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BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PROCEEDINGS

PAPERS IN THIS NUMBER.

"Inverted Siphons for Sewers"—Final Report of Committee.
Memoir of Deceased Member.

MINUTES OF MEETING.

NORUMBEGA PARK, June 15, 1921. — The regular meeting of the Society was held at Norumbega Park, Auburndale, Mass., and was called to order at 6.10 P.M. by the President, Robert Spurr Weston.

There were 33 members and visitors present.

It was voted to dispense with the reading of the minutes of the last meeting.

The President announced that the Board of Government had reinstated Mr. Henry B. Alvord.

The President also announced the death of Mr. Frank J. Nowell on May 25, 1921. Mr. Nowell became a member last February.

It was voted that the President be authorized to appoint a committee to prepare a memoir of John F. Monaghan and one of Frank J. Nowell.

On motion of Col. Gunby, it was unanimously voted that the By-Laws of the Society be changed by inserting the following paragraph:

"Affiliate Sections: The Board of Government may, from time to time, at its discretion, establish Affiliate Sections, which shall be duly organized sections of kindred societies, whose objects are in harmony with those of this Society. The requirements governing such Affiliate Sections shall be those gov-

erning Sections as provided for under these by-laws, so far as applicable, with such modification as may be approved by the Board of Government as necessary to effect suitable working arrangements, having due regard to the interests of this Society."

This vote having been unanimously passed at two successive meetings of the Society, the By-Laws are therefore amended in accordance therewith.

Adjourned at 6.20 P.M.

RICHARD K. HALE, *Acting Secretary.*

APPLICATIONS FOR MEMBERSHIP.

[September 15, 1921.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

BRENNAN, FRED S., Somerville, Mass. (Age 38, b. Boston, Mass.) Educated in Somerville public schools, Boston College High and Y. M. C. A. evening school. Has had experience on building as clerk, assistant superintendent and superintendent, supervising, estimating, designing, etc., for twenty-one years. Refers to J. E. Hanlon, E. S. Parker, G. F. Temple and J. F. Travers, Jr.

MANNING, JAMES HENRY, Brookline, Mass. (Age 38, b. Fall River, Mass.) Graduated from Worcester Polytechnic Institute, 1906. He has had four years experience in field and office on concrete construction, three years

with Stone & Webster Co., Inc., as superintendent of construction on three hydroelectric plants, as consultant, and finally as head of the hydraulic division; three years as chief engineer American International Shipbuilding Corporation, in charge of the planning and designing of Hog Island shipyards; and from August, 1919, to date as assistant engineering manager in administrative charge of the engineering department. Refers to C. M. Allen, F. O. Dufour, C. T. Main, W. N. Patten, A. T. Safford, and D. M. Wood.

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 HUTCHINSON, RICHARD.....June 15, 1921.

LIBRARY NOTES.

BOOK REVIEWS.

CONCRETE DESIGNER'S MANUAL.

Tables and Diagrams for the Design of Reinforced Concrete Structures. By George A. Hool, S. B., Consulting Engineer, Professor of Structural Engineering, The University of Wisconsin, and Charles S. Whitney, M. C. E., Structural Engineer, Milwaukee, Wisconsin. First Edition. McGraw-Hill Book Company, Inc., New York, London. Flexible binding; 6 x 9 in.; pp. 276; diagrams 66; tables 54°. Price \$4.00.

REVIEWED BY FRANK A. MARSTON.*

The use of diagrams and tables greatly facilitates the design of reinforced concrete structures. Therefore, a book which contains well prepared information of this sort is sure to be favorably received by those who understand the principles of reinforced concrete design and who are actively engaged in such work. Like any handbook, the Concrete Designer's Manual will prove more valuable according to the designer's familiarity with its pages.

The diagrams and tables have sufficient range to be of use in the problems generally encountered in the design of buildings, walls, arches, and other engineering structures.

The arrangement of the diagrams is good, they are easy to read, and require only a moderate amount of use to make them as valuable to the designer as his own pet diagram for the design of beams and slabs.

The authors have offered this collection of diagrams and tables to the profession with the belief that they are in convenient form and have been thoroughly tried out in practice. Some of the diagrams are in familiar form, as, for example, the diagram for rectangular beams for values of $\frac{M}{bd^2}$, k , j , and p , which form was originally published by Prof. Arthur W. French in Trans. Am. Soc. C. E., Vol. LVI, p. 362, June, 1906, and since then by many others.

* Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

The Manual is designed to facilitate the design of reinforced concrete structures in accordance with the Joint Committee Recommendations of 1917, the American Concrete Institute Recommendations, the New York Building Code or the Chicago Building Code. A material change in any of these standards will of course affect to some extent the value of the corresponding tables and diagrams. Part of the material in the Manual, however, is of a sufficiently general nature as to be unaffected by the changes above mentioned.

Diagrams are given for values of the allowable stress in concrete of 650, 700 and 750 lbs. per sq. in. respectively; for values of the allowable stress in steel reinforcing bars of 16,000 and 18,000 lbs. per sq. in.; and for values of $n=15$. For some classes of structures somewhat lower stresses, particularly for concrete, have been deemed advisable by some designers.

The tables covering the design of flat slab floors according to three standards for various loadings, both with drop panels and cap construction, will be found particularly suggestive in the preliminary design of floors and roofs.

Considerable space has been allotted to tables covering the design of square and round columns.

The section on "Bending and Direct Stress" contains tables and diagrams that will shorten considerably the work of design in such problems.

The section on "Footings" contains data that will be welcomed by many designers.

No attempt has been made in this review to cover all of the excellent features of the Manual. Its value to the designer will grow with use; and, in addition, many of the miscellaneous diagrams and tables not commonly given in books on concrete design will be found of sufficient worth in themselves to justify the placing of this book in the concrete designers' working library.

COLLECTION AND DISPOSAL OF MUNICIPAL REFUSE.

REVIEWED BY DWIGHT PORTER.*

By Rudolph Hering, D. Sc., New York City, Past President of American Public Health Association and of Engineers Club of Philadelphia, Past Vice-President of American Society of Civil Engineers, member of American Institute of Consulting Engineers, American Society of Mechanical Engineers, Institution of Civil Engineers, London Engineering Institute of Canada, Western Society of Engineers, etc., and Samuel A. Greeley, Chicago, Ill., member of American Public Health Association, American Society of Civil Engineers, Western Society of Engineers, American Association of Engineers, American Water Works Association, Illinois Society of Engineers, etc. New York and London: McGraw-Hill Book Co., Inc. Paper, 6 x 9 in.; pp. 653; illustrated. \$7.00.

The engineering profession will welcome to its literature this treatise on a highly important branch of municipal work. Clear, comprehensive, and admirably presented, it is bound to rank as an accepted standard for many years. Mr. Hering's experience as an engineer, his long and wide professional acquaintance with general sanitary practice on both sides of the Atlantic, and in particular his leadership in movements to develop the art of refuse disposal, and his special investigations of the problem for various cities, have fitted him preëminently to deal with the subject. His younger associate, Mr. Greeley, has been excellently prepared by education, by investigations abroad as well as in this country, by responsible charge of various features of refuse disposal in Milwaukee, and by his specialized practice as a consulting engineer, to collaborate with the senior author.

Preparation of this book was begun some ten years ago. Only about twenty-five years earlier the first organized effort in this country was made, through a committee of the American Public Health Association, to investigate as to the best methods of garbage disposal, and in 1894 Mr. Hering was made chairman of the committee. Present modes of refuse disposal are not in general character different from those approved by that committee. Experience in the intervening years, however, has

* Professor of Hydraulic Engineering, Mass. Institute of Technology.

furnished extensive data, through municipal records, technical analyses and tests, as to quantity and quality of refuse, cost of collecting and of disposing, and has thus made more practicable a logical choice of method for a given community. While further advance may yet be made, through standardized statistics, better organization, and guidance from engineers and sanitarians, the authors believe that the period of conjecture and experiment is nearly past.

As a rule, each chapter opens with a brief introductory outline of the topic to be taken up, and at the close of the chapter there is a concise summary and statement of conclusions. The outstanding features are thus brought into prominence, while details may be found in the intervening pages. The literary style is most attractive, and is worthily supported by judicious subdivision into sections, and excellent typography. Interspersed in the text are some seventy photographic reproductions, and nearly an equal number of drawings and diagrams. In addition, there are not less than one hundred and eighty numbered tables,—possibly a superabundance, but furnishing a large fund of carefully selected data for reference. The value for this purpose, both of tables, and of illustrations, would have been increased by lists accompanying the table of contents.

The general treatment may be outlined as follows: An opening chapter gives definition of terms as used for the different kinds of municipal refuse, a detailed classification of its more common constituents, references to important sources of information, and fundamental data as to quantities of refuse, physical and chemical composition, and the causes and extent of their variations.

Then comes the handling of refuse at its point of origin, prior to collection, here spoken of as "house treatment," which has an important bearing on the appearance of the yards and alleys of a town, and which must be consistent with the method adopted for public collection and disposal. Allusion is made to the exceptional practice of draining house garbage and wrapping it in paper, as required of householders in Minneapolis and Trenton, N. J.; to the temporary cold storage of restaurant garbage in the Pennsylvania Railroad Stations in New York and

Washington; and to the marked effect of the recent war on the amount and composition of city garbage.

Logically, the collection of refuse is next considered, a service which is stated to be normally more expensive than the final disposal. Collection is therefore treated in much detail as to types of equipment, capacity per wagon, frequency of collection, horse-drawn *vs.* motor vehicles, municipal operation *vs.* that by contract, supplemental transportation from relay stations, and so on.

The main problem is that of final disposal. Methods variously open for this are presented in chapters on deposition in water and on land, feeding garbage to hogs, refuse incineration, and garbage reduction. The last mentioned, and distinctly American, practice of treating garbage to secure grease and "tankage" has been favored by the relatively high percentage of grease found in the garbage of our cities, but the authors suggest that in due time this advantage may be lessened by closer approach to the more economical standards of Europe. In spite of the fact that about half of the reduction plants built in this country have been abandoned because of nuisance, fire, or explosion, numerous installations are still in operation in the large cities, in which alone they are profitable.

Disposal of stable refuse, street refuse, night-soil, and dead animals is discussed in final chapters, and, lastly, the important topic of procedure for small towns and villages. Street cleaning is considered too large a subject, however, to be handled with thoroughness in this volume.

Much attention is given throughout to the economics of refuse collection and disposal, as is shown by chapters devoted, respectively, to estimating the cost of collection and transportation, and to estimating costs of final disposal, an article on computations for collection service, diagrams of haulage costs, and a wealth of actual cost data in various tables.

Commendable fairness is shown by the authors in presenting both the advantages and the disadvantages of alternative methods, such, for example, as incineration and reduction. Their purpose plainly is to set forth the principles, and state the facts, upon which may be based a wise choice of method for each particular problem.

RECENT ADDITIONS TO THE LIBRARY.

U. S. Government Reports.

Annual Reports of Library of Congress, 1915, 1916, 1917 and 1918.

Cotton Production in the United States. 1920.

Financial Statement of Cities. 1909, 1910, 1911, 1912. Department of Commerce.

General Statistics of Cities. 1909. Department of Commerce.

Mortality Statistics, 1917. Department of Commerce.

Regional Development of Pulpwood Resources, Alaska. C. G. Smith.

Relation Between Plane Rectangular Coördinates and Geographic Positions. W. F. Reynolds. U. S. Coast and Geodetic Survey.

Statistics of Cities. 1908. Department of Commerce.

Statistics of Railways of United States. 1918. Interstate Commerce Commission.

Special Reports Street and Electric Railways. 1902. Department of Commerce.

Water Supply Papers, 468, 490-B, 471, 500-B.

State Reports.

New York. New York, New Jersey Port and Harbor Development Commission, Joint Report. 1920.

New Jersey. Annual Report of Department of Health. 1920.

Maine. Annual Report of Water Power Commission. 1920.

Maine. Annual Report of Public Utilities Commission. 1920.

Pennsylvania and New Jersey. Report of Board of Engineers to Delaware River Bridge Joint Commission. 1921.

Municipal Reports.

Bangor, Me. Annual Report of Water Board. 1920.

Brockton, Mass. Annual Report of City Engineer. 1920.

Brockton, Mass. Annual Report of Sewerage Commissioners. 1920.

Chelsea, Mass. Annual Report of Water Commissioner. 1920.

Concord, N. H. Annual Report of Board of Water Commissioners. 1920.

Detroit, Mich. Annual Report of Board of Water Commissioners. 1920.

Fall River, Mass. Annual Report of Watuppa Water Board. 1920.

Fall River, Mass. Annual Report of City Engineer. 1920.

Leominster, Mass. Annual Report of City Government. 1920.

Melrose, Mass. Annual Report of Board of Park Commissioners. 1920.

New Bedford, Mass. Annual Report of Engineering Department. 1920.

New York, N. Y. Annual Report of Board of Water Supply. 1920.

Northampton, Mass. Annual Report of City Officers. 1920.

Providence, R. I. Annual Report of City Officers. 1920.

Taunton, Mass. Annual Report of Water Commissioners. 1920.

Waltham, Mass. Annual Report of Department of Public Works. 1920.

Woonsocket, R. I. Annual Report of Board of Water Commissioners. 1920.

Worcester, Mass. Annual Report of Superintendent of Sewers. 1920.

Miscellaneous.

Collection and Disposal of Municipal Waste. Hering and Greeley.

Concrete Designers' Manual. Hool and Whitney.

Engineering Index. 1920.

Handbook of Construction Equipment. Richard T. Dane.

Proceedings of National Association of Cement Users, Vol. 8, 1912.

Rainfall and Run-off in the Miami Valley. Ivan E. Houk. Part 8.

Water Powers of British Columbia. Arthur V. White.

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BOSTON SOCIETY OF CIVIL ENGINEERS

FOUNDED 1848

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications

INVERTED SIPHONS FOR SEWERS
FINAL REPORT OF COMMITTEE

TABLE OF CONTENTS.

REPORT ON INVERTED SIPHONS.

General Features.
Reasons for Installing.
Material. Limiting Size.
Development of Use.
Conditions Affecting Design.
Desirable and Actual Velocities.
Hydraulic Principles.
Profile.
Screens. Settling Chambers. Sumps.
Methods of Cleaning.
Stoppages.
Multiple Pipes.
Buoyancy. Ventilation.
Important Principles.

APPENDIX A.— Data Relating to Inverted Siphons in Massachusetts.

APPENDIX B.— Analysis of Data Received Relating to Inverted Siphons in Massachusetts.

APPENDIX C.— Detailed Descriptions of Certain Inverted Siphons in Massachusetts.

Amesbury, Mass.
Andover, Mass.
Easthampton, Mass.
Gardner, Mass. (3).
Fitchburg, Mass.

APPENDIX D.—Data Relating to Certain Inverted Siphons Outside of Massachusetts.

APPENDIX E.—Notes Relating to Certain Inverted Siphons Outside of Massachusetts.

Aberdeen, Scotland.
Paris, France.
Buenos Aires, Argentina.
Binghamton, New York.
Carlisle, Pa.
Chicago, Ill.
Hattiesburg, Miss.
Louisville, Ky.
Milwaukee, Wis.
New Jersey Joint Outlet.
New Orleans, La.
Philadelphia, Pa.
St. Louis, Mo.
Syracuse, N. Y.
Waterbury, Conn.

APPENDIX F.—References.

JULY 16, 1921.

TO THE SANITARY SECTION OF THE
BOSTON SOCIETY OF CIVIL ENGINEERS:

Your Committee on Inverted Siphons for Sewers begs to report as follows:

The original committee, consisting of W. S. Johnson, R. M. Whittet and D. Porter, was appointed February 3, 1915, to study and report upon "Methods of Design and Construction, and Results of Operation of Inverted Siphons for Carrying Sewage only and for Storm Water."

In March, 1915, preliminary inquiries were sent to various Massachusetts town authorities to learn on what sewer systems inverted siphons were in use. Guided by information thus obtained, blanks were forwarded in April asking for certain descriptive details of each siphon and for data regarding its maintenance. Similar requests were also sent to a number of city engineers and engineers in private practice in New England cities outside of Massachusetts. More or less complete information was secured

for upwards of 90 siphons, with blue-prints for a considerable number of them. Use has also since been made of material found in sundry engineering publications, and by recent additional inquiries, accompanied by blanks, the total number of inverted siphons covered has been increased to about 140.

The data obtained on the earlier blanks were partially arranged later for informal presentation at a meeting of the Sanitary Section held April 5, 1916, which was participated in by half a dozen or more of our members and devoted to a discussion of their experience with the design or maintenance of inverted siphons.

Mr. Johnson, as Chairman of the Committee, then took in hand the papers in the case for the purpose of drafting a formal report, but died October 27, 1917. Mr. Whittet followed as Chairman and intended to prepare the Committee's report, but he died December 10, 1918. What progress, if any, either of these gentlemen made with a report it has been impossible to learn, and none of the original blue-prints or sketches furnished to the Committee can now be found. Nevertheless, the material in hand recorded on the blank forms was thought to warrant presentation, and June 12, 1920, the Committee was reconstituted, to consist of D. Porter, F. A. Marston and H. E. Holmes.

The blanks sent out in April, 1915, called for the following information:

- Name of town and location of inverted siphons.
- Whether on separate or combined system.
- Date of construction, material, and number of lines.
- Diameter, and length on axis.
- Elevation of invert at upper end, lower end, and lowest point.
- Size and slope of sewer at upper and lower ends of inverted siphon.
- Provision in the way of blow-off, overflow or sump.
- Method, if any, provided for flushing.
- Other methods provided for cleaning.
- Names of designing engineer, of person having charge of maintenance, and of person submitting information.
- Sketch plans and profiles.
- Frequency of flushing, or of cleaning by other means.
- Cases of complete stoppage and how dealt with.
- Whether or not siphons are flushed oftener than main system.
- Cost of cleaning.

The following report will present in outline the principles and practice relating to inverted siphons brought out by the Committee's investigation, followed by six appendices which give, successively, a tabulation of data relating to inverted siphons in Massachusetts, an analysis of those data, detailed descriptions of certain inverted siphons in Massachusetts, data and notes relating to certain inverted siphons outside of Massachusetts, and selected references, to numerous of which allusion is made in the body of the report. The accompanying drawings illustrate some types of inverted siphons which have been constructed.

Through misinterpretation of questions or answers and in other ways errors are liable to enter work of this sort, but due care has been taken to secure accuracy and it is believed that the general statements are substantially correct.

General Features.—An inverted siphon is here to be understood as simply a dip or sag introduced into a sewer, which above and below is normally running but partly full and, generally speaking, with but moderate slope. It is illustrated on a small scale by the common running trap on the main drain of a house. Its name suggests its general shape in profile, but otherwise has no warrant, and may mislead into the thought that in some way the distinguishing hydraulic principle of the true siphon is involved, which is not the case. With either the true siphon or the so-called inverted siphon there must be a drop from the inflow water surface to the outlet if there is to be any flow. The length may be indefinitely great. Some of the inverted siphons on city sewers are less than ten feet in length, while several of those built in Massachusetts, in order to reach certain filtration areas, are some thousands of feet long. That built on the outfall line of the Boston Main Drainage Works, between the pumping station and Squantum, conveying sewage under Dorchester Bay, has a length of 7 160 ft. It is 7.5 ft. in inside diameter, averages 142 ft. below low tide, and is conspicuously the longest, largest and deepest inverted siphon in the state. It is also apparently the oldest. What is asserted to be the largest in the United States is that which has recently been built to convey the sewage of New Orleans under the Industrial Canal; it is

10 ft. in diameter, and has a nominal carrying capacity of 2 000 cu. ft. per second. (*Scientific American*, 1920.)

Reasons for Installing.—Occasion for the use of an inverted siphon arises where a sewer encounters another conduit, subway or other underground structure, a stream or a valley, and where it can be carried underneath with far less expense than is involved in any other solution of the problem. An example is afforded by the case of the Lexington Avenue subway in Manhattan, which required inverted siphons at 106th and 110th Streets. These could have been avoided either by lowering the subway for some eight city blocks so as to pass under the sewers, or by building a new trunk sewer in Park Avenue. The former expedient, however, was estimated to increase the cost of subway construction probably a million dollars, besides unfavorably affecting the depth or location of stations, while the new trunk sewer with necessary laterals would have cost probably over a million and a half. The estimated cost of the two inverted siphons, which were finished in 1912, was \$71 000. (Wilson, 1913.)

Material. Limiting Size.—Generally, though not always, the depression at an inverted siphon is sufficient so that the pipe flows with full cross-section and under more or less of a bursting pressure, which it must of course be designed to withstand. In many cases this is so small that a clay sewer pipe can be used with considerable safety, especially if reinforced with concrete, but in a decided majority of the siphons in this state the pipes are of cast iron. Next to that of the Dorchester Bay inverted siphon, the greatest dip reported* is that of the one at Andover, the low point of which is 53.5 ft. below the water surface at the outlet.

Practical considerations, such as the increased danger of stoppage in small pipes, tend to fix the minimum diameters for inverted siphons about as for ordinary sewers,—6 or 8 in. in the separate system and say 12 in. in the combined system, although there are rare examples of smaller sizes.

Development of Use.—The use of metal inverted siphons of large diameter and under relatively high pressure has been practicable since the introduction of iron pipes about 1 700, but

* In Massachusetts.

in sewer practice the device appears not to be old. It was employed more than forty years ago by the eminent English sanitary engineer, Baldwin Latham, who designed six large wrought-iron siphons for the sewerage system of Dantzic, for crossing the Vistula and certain of its tributaries. The earliest example reported to us in this state was that of an 8-in. iron siphon under the Spicket river, on Hampshire Street, Lawrence, built in 1885, although the brick-lined tunnel which forms the inverted siphon under Dorchester Bay was completed two years earlier.

Inverted siphons are not uncommon on pipe lines for water-supply, water-power and irrigation in which nominally clear water is conveyed; but they have been employed on sewers with considerable reluctance, through fear of clogging by foul matter carried in suspension, or by grit rolled along the sewer invert. This reluctance has been naturally and especially felt in the case of combined sewers, with their great fluctuations in volume and their load of débris derived from the streets. The 110th Street inverted siphon under the Lexington Avenue subway, in Manhattan, completed in 1913, is said to have been advised against by two of the most eminent authorities on sewer construction. There the approaching sewer is 10 ft. by 12 ft. in size, "and if the siphon should become choked in a storm it would flood 50 acres of buildings." (Wilson, 1913.) However, this siphon was built, and has given no trouble. It is safe to say that engineers have been generally agreed that inverted siphons should only be employed on sewer lines as a final alternative, where other methods of avoiding an obstruction would be either impracticable or costly. Nevertheless, there has been abundant experience to show that if well designed and looked after they rarely become dangerously clogged and are not unduly expensive to maintain. Emphasis must be placed, however, on the importance of systematic and careful inspection and the prompt removal of obstructions before they form a serious barrier.

Conditions Affecting Design.—There are two distinct conditions under which inverted siphons are adopted, and these have a marked bearing on the ease or difficulty of the problem in a particular case. First, one may be introduced as a feature

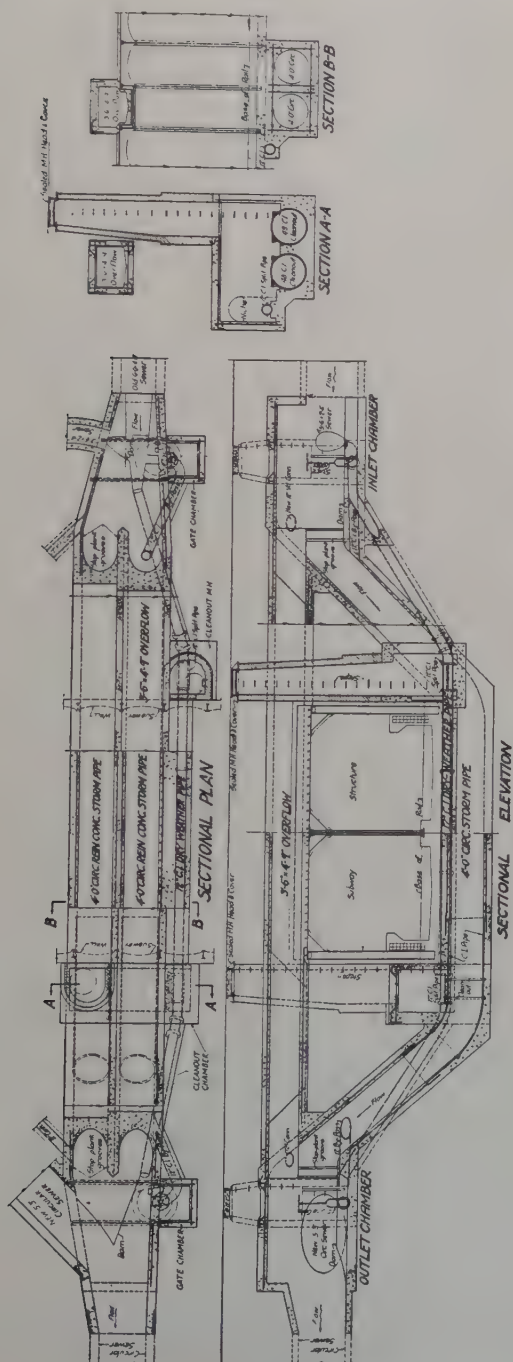


FIG. 1. — INVERTED SIPHON AT MARTENSE ST. AND NOSTRAND AVE., BROOKLYN, N. Y.

foreseen in the original design of a new sewer line; second, it may become necessary to insert one in an old sewer because of the building of some underground structure crossing its course. In the case of the new sewer the designer may presumably provide in advance the necessary drop in the hydraulic gradient for the satisfactory operation of the siphon without causing backwater upstream. But in the case of an old sewer, unless a readjustment of its profile is practicable, the drop will have to be automatically developed by a rise in the water surface upstream, with a resulting increased tendency to deposits there. Many examples of this class have arisen in the larger cities on important sewers of flat slope, conspicuously in connection with subway construction. The first inverted siphon made necessary by New York City subway requirements was built in the Bronx, at 149th Street and Railroad Avenue, and went into service in February, 1902. Nearly a score of others have since been added, the majority in Brooklyn.

Since the principal consideration in the design of inverted siphons for sewers is the prevention of deposits, and since these most easily develop where the foreign matter transported is relatively abundant and heavy, it is seen that the problem varies in character with the type of sewage. That in combined systems is most troublesome, because it comprises a foul domestic and industrial sewage in dry weather, and in storms a vastly larger volume of surface water, bringing with it grit and miscellaneous débris. The dry weather sewage, or that carried at all times in the small pipes of the separate system, has mainly organic matter in suspension, which can be kept moving by very moderate velocities; although in some cases it contains considerable grit which has entered through perforated manhole covers, and other articles mischievously introduced at such points. Exclusively, storm sewers, or drains, have the large variations in flow shown by combined sewers, but are free from the dry-weather flow of foul domestic sewage. Intercepting sewers offer the favorable feature that their flow is mainly of domestic and industrial sewage and tolerably uniform in volume. In the exceptional cases in which inverted siphons are needed on the effluent lines from sewage-treatment plants the conditions are the most favor-

REPORT ON INVERTED SIPHONS FOR SEWERS.

239

DETAILS OF INVERTED SIPHONS UNDER NEW YORK CITY SUBWAYS

LOCATION.	SIZE AND NO. OF PIPES.		CAPACITY OF PIPES, CU. FT. PER SEC.		Total Hor'l Length, including Chambers, in Feet.	Depression of Pipes below Grade Line, in Feet.	Diff. of Inv. Elev. of Chambers, in Feet.	ESTIM. COST.	DATE COMPLETED.
	Storm.	Sanitary.	Storm.	Sanitary.					
149th St. and R.R. Ave., Bx.	2-42"	1-14"	120	6.0	66	9.3	0.1	\$6 000	Feb. 1, 1902
Fulton St. and Hudson Ave., B'klyn	2-24"	1-10"	45	2.52	141	22.0	0.6	8 500	Jan. 3, 1914
4th Ave. and Dean St., B'klyn	2-48"	1-18"	266	11.0	135	13.7	0.9	11 100	July 8, 1911
4th Ave. and Butler St., B'klyn	2-101"	1-16"	680	12.0	100	19.5	0.1 & 0.9	11 900	Aug. 17, 1912
4th Ave. and 7th St., B'klyn	2-72"	1-30"	330	25.0	82	3.4	3.0	4 700	Nov. 25, 1911
4th Ave. and 26th St., B'klyn	2-54"	1-24"	160	15.0	104	2.3	1.1	5 500	Jan. 27, 1912
4th Ave. and 35th St., B'klyn	1-24"	1-6"	19	1.2	117	12.1	1.5	3 800	Sept. 21, 1912
Lex. Ave. and 106th St., Man.	2-48"	1-24"	80	9.8	159	13.8	0.15+	19 000	Oct. 19, 1912
Lex. Ave. and 110th St., Man.	2-78"	1-42"	356	19.6	256	15.5	0.26+	52 000	Jan. 7, 1913
So. Boulevard and 144th St., Bx.	2-30"	1-8"	50	0.9	115	15.4	1.0	4 000	.....
So. Boulevard and Longwood Ave., Bx.	2-30"	1-8"	61	0.65	134	11.7	3.5	5 000	.....
So. Boulevard and 149th St., Bx.	2-48"	1-14"	225	6.5	83	11.3	0.83+	11 000	.....
65th St., bet. 21st and 22nd Aves., Bx.	1-16"	1-8"	68	0.8	162	10.4	0.66	2 100	Sept. 22, 1914
20th Ave., bet. 63rd and 64th Sts., Bx.	1-24"	1-8"	14	0.7	137	11.4	0.45	1 500	Aug. 20, 1914
7th Ave., at 18th St., Man.	2-60"	1-24"	360	20.	212	8.2	0.65	18 000	.....
Nostrand Ave. and Martense St., Bx.	2-48"	1-12"	68	1.36	102	14.48	0.07	8 200*	.....
Nostrand Ave. and Clarendon Rd., Bx.	2-36"	.....	49	0.74	86	14.25	0.13	4 200*	.....
Nostrand Ave. and Farragut Rd., Bx.	2-63"	1-20"	263	6.82	124	12.75	0.10	9 400	.....
Nostrand Ave. and Foster Ave., Bx.	2-54"	.....	144	.....	99	18.56	0.10	4 200	.....
Nostrand Ave. and Beverly Rd., Bx.	2-54"	1-14"	153	2.84	152	15.85	0.50	6 400*	.....

* Includes cost of overflow.

able of all, since the liquid approximates more or less closely to clear water.

Desirable and Actual Velocities.—A serious obstruction being more difficult to remove from an inverted siphon than from an ordinary sewer, especial care should be taken to prevent its formation. The design, therefore, should aim to insure at all times at least as high a velocity through the siphon as would be considered necessary to prevent deposits in the approaching sewer,—say from 2 to 3 ft. per second for domestic sewage, and 3 or more ft. per second for combined sewage. If it is impracticable in a particular case to provide head for such velocities, then correspondingly greater reliance must be placed on artificial flushing or other means of cleaning the siphon.

Comparatively few data are available regarding velocities actually prevailing in inverted siphons. Mr. J. L. Woodfall has given the average velocity in the Gardner, Mass., siphon, built in 1890, as about 0.4 ft. per second in 1904, and yet, in spite of this low value, flushing had not been thought necessary for several years. (Bos. Soc. C. E., 1904.) For the Gardner siphon built in 1900, Mr. Woodfall gave the average velocity, in 1904, at about 0.3 ft. per second, and for the siphon for Andover, Mass., 0.25 ft. per second. None of these carried storm water.

In an article in *Engineering and Contracting*, July 15, 1914, Mr. F. H. Carter gave the following range in velocities in inverted siphons on the Metropolitan main sewers in the vicinity of Boston:

Shirley Gut	1.92 — 2.70 ft. per sec.
Chelsea Creek, East Boston	2.31 — 3.25 ft. per sec.
Malden River	1.19 — 3.49 ft. per sec.
Mystic River, Boston	1.54 — 2.99 ft. per sec.
Aberjona River, Medford	1.80 — 2.82 ft. per sec.

Hydraulic Principles.—The actual velocity of flow in ft. per second through the pressure pipe of the inverted siphon, which in most cases has sufficient sag to flow full, will of course be equal at any time to the actual volume of flow in cu. ft. per second, divided by the area in sq. ft. of the internal cross-section. In designing, the volume to be anticipated must be estimated as

for any sewer, or in case the siphon is to be introduced into an existing sewer, the known or computed discharging capacity of the latter may be thought proper to use. The volume divided by the value it is decided to assume as a reasonable minimum velocity gives the necessary area of cross-section of pressure pipe, which may be approximated by the selection of a suitable commercial diameter.

The total head (H , see Fig. 2) or drop in the hydraulic gradient actually required at any time for the then-existing flow will be the difference in level of the free-water surfaces at

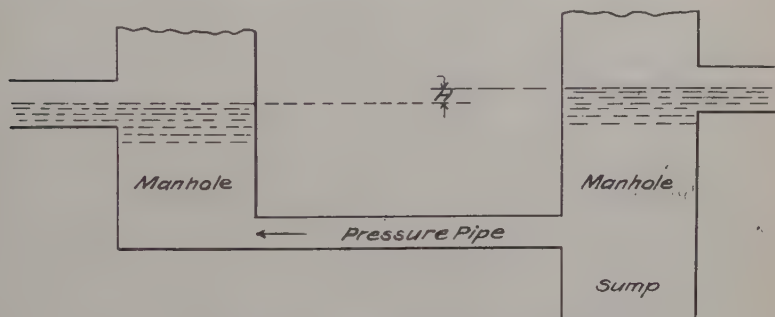


FIG. 2. — OUTLINE OF SIPHON SHOWING WORKING HEAD AND AVAILABLE HEAD.

the two ends of the siphon. It will equal the sum of the friction head, as determined by the actual length of the siphon measured along its axis, the head lost at any bends, and that lost by any abrupt changes of cross-section, as at entrance from an upstream manhole into the pressure pipe, or from the pressure pipe into a downstream manhole. Theoretically, it may also in some cases cover a small value, plus or minus according to circumstances, due to difference of velocity heads in the approaching and departing sewers. The determination will be parallel to that for any similar conduit carrying clean water, but the friction loss is likely to be increased a varying and uncertain amount by the more or less foul condition of the interior of the pressure pipe, and a serious local obstruction in that pipe may cause, while it lasts, a relatively large loss of head of indefinite size. Losses

of head due to bends and changes of cross-section are difficult to estimate closely. Those caused by bends alone are likely to be trifling with low velocities, and may be diminished by using curved elbows. Those accompanying a square-edged entrance from an upstream manhole into the pressure pipe are more important, but may be reduced by rounded edges or a flaring entrance. On the whole, it seems wise to be liberal in estimates of total loss of head. It is to be remembered that the losses will be relatively small for low velocities, other things equal, but that they increase roughly as the square of the velocity. For a siphon of the type illustrated in Fig. 2, with a clean 12-in. iron pressure pipe 50 ft. long, and a velocity nowhere exceeding 3 ft. per second, a total loss of head of 6 in. would probably be an outside value; for a velocity of 2 ft. per second, 3 in.; but for 6 ft. per second, 24 in. The friction loss alone in this case would be not over one-fourth the above values.

The head offered by the construction of the inverted siphon will in general be about the difference of level of the inverts of the approaching and departing sewer at the ends of the structure. If the condition of flow demands at any time a greater head than this, it will be automatically built up by the sewage itself, through a rise of level in the upper sewer, with a corresponding slackening of the velocity there. This may be objectionable.

Since the volume of flow is bound to be more or less variable, the actual total head (H) to meet the losses in the inverted siphon must also vary. It will change from hour to hour, and will also increase year by year as the tributary drainage district becomes more developed and its sewage or storm-water discharge becomes greater. As time goes on, if the increased head thus required is not available, relief may be had by building, or putting into commission if already built, one or more additional lines of pipe. This provision is frequently made at the start for inverted siphons taking sewage from a combined system, the best practice reserving one of the pipes exclusively for dry-weather flow.

Interesting experiments have been cited by J. L. Woodfall (Bos. Soc. C. E., 1904), as having been made by the Massachusetts State Board of Health on the Gardner inverted siphon built

in 1890. These showed actual losses of head, after flushing, varying under two different rates of flow from about 1.9 to about 2.2 times the loss computed as theoretically correct for a clean pipe. Before flushing, and some seven months after the last previous flushing, the measured loss of head was roughly 3.5 times that computed for clean water in a clean pipe. This was a 12-inch iron pipe, 1 050 ft. long.

Profile.— The longitudinal profile adopted for an inverted siphon will be influenced in part by the profile of the surface under which it passes, in part by the nature and position of underground structures which the siphon is built to avoid, or of the material to be encountered, and in part by a desire to make it so far as possible self-cleansing. If it passes under a stream, or a valley, it is likely to show inclines at the two ends joined by a relatively flat section. If of short length, as in passing under another conduit in a cross street, it often consists of a vertical well or manhole at each end, with a straight connecting pressure pipe, having more or less grade toward the well at which pumping is proposed to be done in emptying and cleaning the pipe. Where the water carries heavy matter in suspension or rolled along the sewer bottom, as in the case of storm flow, an upward slope at the downstream end is more favorable than a vertical rise for carrying the grit out of the siphon. In cases where there is but scanty head available and its conservance is important for avoiding back-water upstream, inclines at the ends involve somewhat less loss of head than vertical wells. Inclines are a feature of all the inverted siphons used on the combined sewers intersected by the New York City subways, with the exception of that at Hudson Avenue, Brooklyn. There one leg of the siphon had to be constructed in a limited space between the walls of the old and the new subway, and was made vertical.

Screens, Settling Chambers, Sumps.— The subsidiary features of inverted siphons are mainly aimed at intercepting material which might clog the pressure pipe, or at providing for the efficient cleaning of the pipe if it should become fouled or obstructed. In substantially all cases there is a manhole at each end of the siphon, providing access for inspection and cleaning. It is

possible for clogging material to be held back from the siphon by screens or settling chambers. Screens appear to be used but very exceptionally, unless for the protection of neighboring pumps. Such an arrangement is described by Baldwin Latham for the inlets of the inverted siphons at Dantzic, conveying sewage under two navigable channels to the pumping station, which is located on an island. Boston sewage is screened before reaching the siphon under Dorchester Bay, but the screens are above the pumping station. The upper end of the Andover, Mass., inverted siphon starts from a screen chamber intended to remove large solid matter; and just above the Commercial Street siphon under the Lechmere Canal, in Cambridge, there is a bar screen, which is regularly examined and cleaned. During the construction of the Brooklyn inverted siphons made necessary by subway work the use of bar screens above siphon entrances, to keep out large floating materials, was considered, and to test its practicability a temporary wooden screen was set up in a large sewer leading to one of the siphons. Within two days "it was completely covered for the depth of the flow with rags, paper, twine, wood and other débris, effectively blocking the flow, and showing conclusively that any such device would form a dam in a very short time. Mechanically rotated screens, such as are used in sewage purification plants, would serve the purpose, but could not be used owing to the cost of maintenance." (Hunt, April, 1917.)

Heavy matter can be intercepted by settling. If such provision is made it logically should be at or near the upstream end of the inverted siphon. Also, unless very frequent removal of the deposit can be relied upon, the settling chamber needs to be of considerable size, else it may soon become filled and no longer serve its purpose. In numerous cases in this state the upstream manhole is continued below the entrance to the pressure pipe so as to form a sump. Ordinarily this appears to be not more than two or three ft. deep. It may be convenient if the siphon has to be pumped out, and useful as an interceptor of pieces of brick, stone or metal, but merely as a silt-catcher its value seems to be open to question. There is a wide difference in practice regarding the employment of sumps. On 16

inverted siphons for which returns were received by this Committee sumps are provided at the upstream end, on 32 at the downstream end, on 17 at both ends, and on 58 at neither end. The first inverted siphon built because of New York subway construction, that at 149th Street and Railroad Avenue, had a sump at the upstream end, but after seven years of experience with it the engineers of the Public Service Commission recommended its omission from subsequent designs, as being unnecessary. (Hunt, April, 1917.)

Some 1500 ft. above the head of the inverted siphon on the main sewer from Fitchburg, Mass., to the sewage treatment plant, there is a grit chamber about 50 ft. long, designed to intercept grit larger than $\frac{1}{16}$ in. in diameter.

At the head of the inverted siphon under Dorchester Bay, on the Boston Main Drainage system, there is a settling chamber, in the form of twin "deposit sewers," 1260 ft. long, arranged to insure a velocity not exceeding 1 ft. per second.

In their report on The Riverbank Subway (1909), Kuichling and Bryant describe the practice of Belgrand in installing, upstream from the inverted siphons of the Paris sewers, detritus channels from 300 to 600 ft. in length, and of sufficient cross-section to reduce the mean velocity of flow to about 0.5 ft. per second.

Methods of Cleaning.—The cleaning of deposits from a fouled inverted siphon is usually effected by flushing, or, if necessary, by handwork with rods and scrapers. Various methods in use in ordinary sewer cleaning are applicable.

The theory of flushing is temporarily to increase the velocity through the pressure pipe enough to give it scouring force. The necessary volume is obtained either by holding back for a time the approaching sewage and suddenly releasing it, or by introducing flushing water from an outside source. In any case, an increased head on the siphon is called for, which in some instances may be possible only by the creation of back-water upstream. Methods in use for flushing comprise

(a) The temporary speeding up of pumps, if there is a pumping station on the sewer line.

Baldwin Latham describes the inverted siphons which convey crude sewage under the Mottlau and Keil-Graben channels at Dantzic to the pumping station as fitted with gates at the head so that, by temporarily holding back the flow and pumping out the sewage-well at the pumping station, and then starting up the pumps, a velocity as high as 9 ft. per second could be maintained for a time through the siphons. (Latham, 1878.)

It is stated by Mr. E. S. Dorr that when the Dorchester Bay inverted siphon of the Boston Main Drainage Works was built in 1883, a plan was contemplated for flushing it by passing through a ball of somewhat less than the 7 ft. 6 in. diameter of the tunnel, and that such a ball was actually made. There has been a reluctance, however, to introduce any such possible obstruction into the tunnel, and all cleaning has been accomplished by temporarily speeding up the velocity of flow. By measuring the loss of head between the ends of the siphon the hydraulic slope may be computed, and by employing the pumps as meters the volume of flow may be approximated. The value of C in the Chézy formula may thus be determined, an abnormally low value indicating foulness of the siphon, while progressively higher values reveal the success of efforts at flushing. In the early experiments values as low as about 80 were obtained before flushing, and as high as between 140 and 150 after flushing. Increased velocity for flushing is obtained by proper manipulation of the pumping units, admitting sea water to the pump wells if there is not enough sewage and storm water. At the entrance to the tunnel shaft provision was also made for suddenly tripping gates controlling the depth of flow in the approaching "deposit sewers," and thus admitting a powerful flush into the tunnel, but it has not been utilized. There is also provision at that point for by-passing the entire sewage flow around the shaft entrance and discharging it, in case of emergency, directly into Dorchester Bay. (Clarke, 1885.)

(b) Receiving the sewage flow at the head of the inverted siphon into flush tanks which automatically discharge when full. At Concord, Mass., at the head of two distinct 8-in. siphons crossing the Sudbury river are such flush tanks, one of 7 400 gallons and the other of 1 570 gallons capacity, discharging from 10 to 14 times a day. One of these is illustrated in *American Sewerage Practice*, Vol. I, p. 576.

(c) Providing a permanent flushing gate at the manhole at the head of the inverted siphon, or else grooves for the insertion of stop-planks when desired. This not only permits temporary storage of sewage in the approaching sewer, and the building up of an increased head for flushing, but allows isolating the

siphon for flushing from an exterior source, or for pumping out in case hand cleaning is necessary. Examples are found in the siphon of the Metropolitan main sewer at Portland and Main Streets, Cambridge, for which there is a flushing gate; and on four of the siphons at New Bedford, in which stop-planks may be inserted.

(d) Opening a blow-off at the low point of the pressure pipe of the inverted siphon. This is possible only in the exceptional cases in which there is a drainage channel low enough to receive the discharged water, but for a long pipe with large dip should give a powerful flush. It not only removes much accumulated deposit from the siphon, but empties the pipe for further cleaning without the necessity of pumping.

The 30-in. inverted siphon, 5 300 ft. long, on the sewer line from Fitchburg to the treatment plant, drops about 52 ft. from its upper end to its lowest point at the Nashua river, and is there provided with a 24-inch blow-off, discharging into the river.

The first inverted siphon at Gardner, built in 1890, is a 12-in. iron pipe, 1 050 ft. long, dropping about 25 ft. from the upper end to the low point, where a blow-off permits draining the siphon onto a small filter bed. A similar provision was made on the 12-in. siphon, 4 980 ft. long, built at Andover in 1898; this drops 66 ft. from upper end to low point, where the blow-off and small filter bed are located.

(e) Admitting clean water at the head of the inverted siphon from a permanent connection to a street water main, or through a hose line from a neighboring hydrant. The Andover siphon above referred to has a permanent connection to a 6-in. water main, and there are numerous other examples of this arrangement in the state. This method has also been provided for flushing the dry-weather pipe of the inverted siphons necessitated by subway construction in New York City, in cases where the pipe, though of minimum allowable diameter, nevertheless has at times too small a flow to prevent deposits. The inference seems fair that in the ordinary run of cases in this state flushing is effected with water from a hydrant. In a discussion by the Sanitary Section in October, 1904, it was stated by Mr. C. R. Felton that in the various inverted siphons in Brockton the velocity did not usually exceed 0.7 ft. per second, but could be increased by flushing to about 8 ft. per second.

(f) It is occasionally possible, in the case of an inverted siphon under a river, to introduce river water through a special connection to the chamber at the head of the siphon. This is done at Brockton, at the West Bartlett Street siphon.

Cleaning of inverted siphons by hand generally implies the use of jointed rods, with suitable scrapers or other tools at the end. The pipe to be cleaned must be emptied of water by draining at a blow-off, or pumping at a manhole; and during the cleaning operation the flow of sewage must be diverted through another pipe, if the siphon has more than one, or held back in the approaching sewer, or discharged through an overflow into a stream, if that be feasible. Such an overflow may serve the additional purpose of relieving the sewer of surplus water during storms, if the system be on the combined plan. The inverted siphons carrying combined sewers across under the subways of New York City usually comprise one small pipe for dry-weather flow, ranging from 8 to 42 ins. in diameter, and two much larger pipes for storm water. There is an incline at each end of the siphon, with a flat section between, under the subway floor. To facilitate cleaning of the dry-weather pipe, in case it becomes obstructed, the practice has been in recent years to provide a by-pass, of the same size as the dry-weather pipe, at each end of the siphon, controlled by sluice gates and leading into one of the storm-water pipes. By building temporary dams of sandbags in the dry-weather-flow channel at the ends of the siphon, the sewage can be diverted around the intervening pressure pipe, which is then available for emptying and cleaning.

The manhole or clean-out chamber at each end of a siphon gives access for rodding, for pumping, and, in the case of pipes of large size, for entrance. If the siphon is built with inclines at the ends, joined by a flat section, it is advantageous to have access also at the foot of the slopes, and in the later New York practice, above alluded to, an additional manhole leading to a clean-out chamber has been provided at those points. There the pipes have removable cast-iron covers, by which the interior may be opened up for pumping out the last of the water and for rodding.

At several of the New Bedford inverted siphons built in 1913, special provision is reported for the insertion of clean-out rods.

There is some objection to intermediate manholes on an inverted siphon if the sewage is free to rise in them, since grease

and other scum tends to fill up the shaft in time with a solid plug. Examples of this are found in the Dorchester Bay inverted siphon at Boston, and in a 36-in. inverted siphon under the Brandywine river at Wilmington, Delaware.

English treatises on sewerage have usually advocated installing in an inverted siphon a chain or a copper-wire rope, which might be worked back and forth, when necessary, to loosen deposits, supplementary flushing being used to sweep out the stirred-up material. The method does not appear to be used noticeably in this country, although a stoppage is reported to have been removed from the 10-in. Auburn Street siphon in Medford by dragging a rope through it.

With lapse of time it must happen with some inverted siphons carrying sewage that the interior will become more or less fouled, and as a result the effective cross-section diminished and the velocity and necessary working head increased. The tendency will be in such a case toward a condition of equilibrium, in which the velocity will have become sufficient to prevent further clogging, and evidence is occasionally noted that this has happened. In other instances a temporary increase in the volume of sewage, as, for example, following a rain, may cause a natural flushing action which will sweep out wholly or in part accumulated deposits. It may thus happen that a partially clogged inverted siphon will operate for years without causing serious trouble.

In a discussion by the Sanitary Section in October, 1904, (Bos. Soc. C. E., 1904), Mr. J. L. Woodfall cited evidence of an intermittent discharge of sludge from the Gardner siphon, built in 1890, which he attributed to the building up of head with increase of deposit, until a point was reached at which the mass was rapidly discharged. He also mentioned an instance in which stone dust from street macadamizing had been washed into the sewers through perforated manhole covers during stormy weather, and had settled in the siphon, but was suddenly flushed out to the extent of several cubic yards following an especially heavy rain.

In the discussion by the Sanitary Section, April 5, 1916, Mr. Otis F. Clapp described a 48-in. inverted siphon, 774 ft. long,

under the Providence River, at Providence. This has vertical shafts at the ends, with a sump, 5 ft. deep, at the upstream end. Repeatedly this sump has been found filled with deposit, but a subsequent slight rain would sweep it all out.

In the same discussion, Mr. L. M. Hastings spoke of the 24-in. inverted siphon under Lechmere Canal, in East Cambridge. This has a sump 5 ft. in diameter at the downstream end, which appears to remain constantly full of a muddy deposit, except for a passage through it, say a foot in diameter, which is kept sufficiently open by the flow of sewage, so that it has proved necessary to clean the siphon but once since it was built in 1894.

Further evidence on the point under consideration has been furnished by Mr. A. L. Shaw, Assistant Designing Engineer with Metcalf & Eddy, in the following communication to the Committee, dated August 30, 1920:

"While making a recent investigation along the Brandywine River in Wilmington, Delaware, the writer had occasion to note the operation of an inverted siphon, 36 in. in diameter, which crosses the river a short distance below the bleaching and finishing plant of the Joseph Bancroft & Sons Co. . . .

"The siphon is of reinforced concrete (built about 1908), and has at its upper end a series of chambers which imperfectly intercept grease and sediment, and from which the wastes (including a relatively small amount of sanitary sewage) pass over a brick wall, into a well or shaft about 9 ft. deep and about 3 ft. by 3.5 ft. in cross-section. A 30-in. concrete sewer leads into these chambers at the upper end, and from the bottom of the shaft at the lower end the 36-in. siphon leads off on a falling grade for about 220 ft. to its lowest point, at which there is a manhole, with cover above the normal hydraulic gradient. From this low point the siphon runs on a gradually ascending grade for about 200 ft. to a manhole, where it meets the grade of a 36-in. concrete gravity sewer. The maximum depth of the invert of the siphon below the ordinary water level in the central manhole is about 9 ft. The capacity of the 30-in. sewer above the siphon is about 16 mgd., and that of the 36-in. sewer below is about 24 mgd."

From suitable measurements, Mr. Shaw was able to compute the probable velocity of flow through the net opening in the siphon, which was believed to be considerably fouled by deposits.

That velocity ranged at three different observations from about 2.7 to 4.0 ft. per second.

"The apparent velocities in the reduced cross-section of the siphon are remarkably close to the velocities generally accepted as those necessary to maintain scouring (3 to 4 ft. per sec.). This suggests the probability that sedimentation had proceeded until the section was so reduced as to increase the velocity to the point where further deposits were prevented, establishing a state of equilibrium. This case perhaps illustrates why neglected siphons sometimes operate for years without giving serious trouble, deposits accumulating until the increased velocities automatically maintain a minimum opening. . . .

"The manhole at the low point of the siphon has proven a source of trouble. Grease and other floating matter are trapped in this manhole as they pass along under pressure in the siphon beneath. This results in the accumulation of a very putrid mass, which floats on the surface of the water near the top of the manhole and has been occasionally forced out and into the river at times of high discharge in the sewer, when the hydraulic gradient lies above the top of the manhole, due to the increased resistance of the partially choked siphon. Aside from this objectionable overflow, which of course could be overcome by raising the manhole, this instance emphasizes the undesirability of any interruption in the continuity of the bore of a siphon pipe, unless this is absolutely necessary in order to provide clean-out facilities."

Stoppages.—While as a rule the inverted siphons which have come to the Committee's attention appear to have given uninterrupted service, without undue expense for maintenance, there have been some exceptions in both these respects. Returns for this state give brief notes of serious stoppages in fourteen cases,—nine on separate systems, five on combined, and for diameters ranging from 6 to 24 ins. for each type. They are set forth in some detail elsewhere, but definite information as to the causes of stoppage was not furnished. In discussions it has appeared that not only grit and gravel, but masses of rags, cotton-waste, bent wire, tin cans, accumulations of grease, and other débris, even occasionally paving stones, have to be reckoned with as possibilities.

A remarkable, but highly instructive, instance of stoppage was that of the inverted siphon at Dean Street and Fourth

Avenue, Brooklyn, which was completed in July, 1911, and five years later became almost completely obstructed, giving the first and only important trouble experienced with inverted siphons built in connection with the New York subways. As described by Mr. J. L. Hunt, in a paper in *Municipal Engineers Journal* for 1917:

"The cleaning of this siphon proved to be an extraordinary and costly undertaking. The siphon consisted of two 48-in. pipes for the storm flow and one 18-in. pipe for the dry-weather flow, and replaced a portion of the 72-in. circular sewer in Dean Street. This sewer extends through Dean Street to Flatbush Avenue, where, fortunately, at the time, the subway excavation was in progress, which served as a reservoir for the back water. When the Sewer Department's cleaning force with their equipment arrived on the job there was a little flow passing through the siphon, but the water had risen to a considerable height in the manholes. They endeavored to rod the pipes and to free them by means of a water-jet, but owing to the depth of the sewage in the upstream chamber their efforts were futile. In the meantime, the situation was getting worse; water was backing up into the Pacific Street Station of the Fourth Avenue Subway through the toilet and ventilator drains, and threatened to stop the operation of the trains. Work on the Flatbush Avenue Subway in the vicinity of Dean Street had to be stopped on account of the depth of water in the cut, and a number of property-owners were complaining of the increasing depth of water in their cellars. The available pumps and men of the Sewer Department were inadequate for the task, and it was evident that immediate and unusual measures had to be adopted to combat the situation. In the emergency the subway contractor on the adjoining contract was called upon to assist in this work and was authorized to use every means at his disposal to speedily relieve the dangerous conditions. Accordingly, three or four large centrifugal pumps were set up in a short time at the different manholes in Dean Street and the sewage was temporarily pumped to the street surface, along which it flowed to a basin and manhole on another system. But although these pumps were more than sufficient to handle the dry-weather flow, they would occasionally get clogged with the heavy sewage, as the water was lowered, and it was not until a sand pump was procured and put in operation that it was possible to enter the upstream-siphon chamber to get at the seat of the trouble. This consumed about four days. . . .

"When it was possible to enter the siphon chamber it was found that the entrance to all three pipes was completely obstructed with a mound of *débris* consisting principally of a mattress, a load of lumber of various sizes, a long-handled shovel, a piece of blue-stone curbing, a wooden barrel, several iron pails, brick, pieces of concrete, tin cans, broom handles, umbrella frames, together with rags, wire, paper and other refuse. As soon as this rubbish was removed from the entrance to the pipes the sewage started to flow through them, and with the aid of a water-jet was soon flowing freely. The small pipe, however, had to be thoroughly cleaned.

"The most important conclusion to be drawn from the stoppage is that all inverted siphons should be regularly and carefully inspected and all obstructing materials removed from the chambers before a dam is formed by their accumulation. The dry-weather pipe should also be periodically cleaned. It is not likely that storm pipes as large as those at Dean Street will become clogged unless the small pipe is obstructed and left in that condition for a considerable period, but a regular inspection will reveal when this pipe is not properly carrying the flow, and it is a comparatively simple task to clean out this pipe by temporarily diverting the flow into the storm pipes. . . .

"This stoppage also shows that it is a wise precaution to construct an emergency overflow wherever possible, as low as conditions will permit, so as to provide an outlet when the siphon is obstructed. In connection with the Dean Street trouble, it was found that the chamber manholes were too small for pumping operations and at the same time to permit access with the necessary paraphernalia for cleaning. It also showed that it would be a good plan to construct clean-out manholes at the lower bends of the storm pipes as well as on the dry-weather pipe, to facilitate cleaning when necessary. Even though the storm pipes are big enough for a man to enter, it is hazardous work when all the cleaning has to be done from within the chambers. These clean-out manholes provide additional points of attack for cleaning, and the work is less dangerous and more rapidly accomplished."

Multiple Pipes.—While about three quarters of all the inverted siphons in Massachusetts for which returns were made have but a single pressure pipe, allusion has been made to the use of multiple pipes,—most often two in this state, nearly always three under New York City subways, and elsewhere even four, as under Wissahickon creek, Philadelphia. (Metcalf & Eddy, 1914.) In the separate system, additional siphon pipes

accommodate the increased volume of sewage that comes with lapse of time, without increasing the working head; at the same time, if provided with suitably arranged terminal chambers, any one pipe may be isolated temporarily for cleaning, and the sewage flow taken by the other pipes. In the combined system, because of the great variations in flow between dry-weather and storm conditions, the use of two or more pipes is especially advantageous, one being reserved for dry-weather flow, while storm flow spills over side walls or weirs in the entrance chambers at the head of the inverted siphon, into the special storm pipes. This arrangement has proved highly satisfactory on the combined system of Boston, and has been systematically used for the inverted siphons crossing under the New York subways. There the crest of the dam, or dams, at the upstream end of the siphon, has been put at about the computed height of the water surface for the full assumed dry-weather flow, after making due allowance for the probable loss of head in forcing that flow through the siphon. There is a similar dam, or dams, also at the downstream end of the siphon, so that in dry weather there is no chance at either end for foul sewage to enter a storm pipe. Where two or more storm pipes are installed, their entrances are usually at a common level, and likewise their exits. If desired, however, the entrances may be on different levels, and in that case the exits also, the pipes coming into play successively as the volume of rain-water increases. This plan was applied to the inverted siphon at Fourth Avenue and Butler Street, Brooklyn, but is thought not to offer advantages sufficient to commend it for general use.

Buoyancy. Ventilation.—An inverted siphon on the bed of a stream may have a dangerous buoyancy when empty, and care is therefore needed that it be sufficiently weighted to overcome any tendency to float.

English authorities on sewerage have in the past emphasized the importance of ventilating long inverted siphons, and especially the descending leg, asserting that otherwise the flow may be interfered with by accumulated air or gas. This difficulty does not appear to have been met in American practice, and no special provision for dealing with it has been brought to attention.

There have been some noteworthy instances, however, of disintegration of concrete in the vicinity of inverted siphons, which is thought to have been due to the evolution of hydrogen sulphide from especially stale domestic sewage, or from industrial liquids containing sulphur, the absorption of this gas by the condensed moisture on the exposed sewer walls, the subsequent formation of sulphuric acid, and its action in uniting with the lime of the cement to form sulphate of lime and thus to disintegrate the concrete.

The old Los Angeles outfall sewer, built in 1895, included two wood-stave inverted siphons, each about 3.4 miles long, joined by a section of brick-lined tunnel. The velocity through the siphons was very low, the time of passage long, and the condition favorable for putrefaction and the formation of foul gases. A strong odor was particularly noticeable at the outlet from the upper siphon and at a 12-ft. vertical drop in the sewer about a mile and a half downstream, and at these two points the disintegration was most severe, being confined to that part of the sewer above the ordinary water level. The damage became pronounced within a few years after the completion of the outfall, and was ascribed by Mr. Rudolph Hering, who investigated the case, to lack of ventilation. (Hardesty, 1906, and *Eng. News*, Nov. 8, 1900.)

There has been similar experience at the inverted siphons of the Metropolitan Sewerage Works of the Boston district, according to information received from Mr. F. D. Smith, Chief Engineer. The lines are long and the sewage is quite stale when it arrives in the lower reaches. The trouble is more serious, therefore, other things equal, as the outfall is approached. It was first observed at the Shirley Gut siphon, which is nearest the outlet of the North Metropolitan System. The upper man-hole there was closed at a certain time and caulked tight, remained so for a year and a half, and was then opened up. The mortar of the brickwork on the approach side of the siphon was found soft, like putty, the brickwork between stop-plank grooves had peeled off in places, and some bricks in the roof arch of the sand-catcher had dropped out. There had been less action on the downstream side of the siphon. This siphon was the worst

on the Metropolitan System in the matter of disintegration. There was some at the Belle Isle Inlet siphon, but the ventilation was better there than at Shirley Gut. There was trouble also at the inverted siphon under the Aberjona river in Winchester, where the exposed surface sloughed off to a depth of perhaps half an inch.

Important Principles.—The extended and varied experience of the engineers of the New York City Public Service Commission in the designing and building of inverted siphons on combined sewers under difficult conditions should be of much value to other engineers, and the following essential principles as set forth in a paper by Mr. S. D. Bleich (Bleich, 1917), commend themselves to attention:

- “1. Complete and effective separation of the house sewage and industrial waste from the storm run-off at all times.
2. Simplicity of construction.
3. As slight and easy changes in direction of flow as are practicable at the entrance and exit legs.
4. Easy curves where necessary.
5. Uniform section throughout entire length of siphon pipes.
6. Elimination of all features tending to obstruct flow.
7. Omission of all moving parts and mechanical devices.
8. Provision for easy access to all pipes without impairing any of the essential features.
9. Entrance and discharge openings to have sufficient area within the available height not to cause any back-water; and change of section or direction not to be too abrupt.”

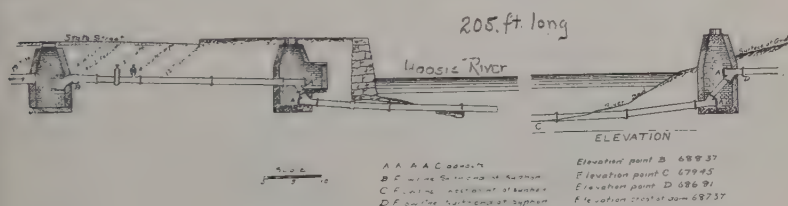
Respectfully submitted,

DWIGHT PORTER,
FRANK A. MARSTON,
HARRY E. HOLMES.

APPENDIX B.

ANALYSIS OF DATA RECEIVED RELATING TO INVERTED SIPHONS
IN MASSACHUSETTS.

Massachusetts cities and towns having sewerage systems number 110, to all of which application was made for information, and from 45 of which data have been received regarding one or more inverted siphons. About two thirds of all the 145 individual siphons reported are on the domestic sewers, or the separate system; about one quarter on combined sewers or surface-water conduits; eight on Metropolitan main lines; and the remaining few were not specified as to type.



FROM ANNUAL REPORT, CITY ENGINEER, 1900

FIG. 3. — INVERTED SIPHON IN STATE STREET LINE OF SEWER,
NORTH ADAMS, MASS.

The earliest to be built was the Dorchester Bay inverted siphon of the Boston Main Drainage Works, which was completed in 1883, followed by an 8-in. line under the Spicket river, on Hampshire Street, Lawrence, in 1885; but one third of the whole number belong to the five-year period, 1893-1897.

The nature of the obstacle which led to the use of an inverted siphon in individual cases was not generally stated, but for a total of about forty siphons was given as brook, river, or tidal water; other sewers, surface water conduits, water mains, and railroad lines accounting for from five to ten examples each; with a few scattering ones otherwise explained.

Cast iron has been used for the pressure pipe of the inverted siphon in more than two thirds of all the cases reported. For

some twenty siphons clay sewer pipe has been used, in a few cases reinforced with concrete, as in the Metropolitan main line under the Aberjona river, in Winchester. Concrete has been employed in nearly a dozen cases, about equally divided between plain and reinforced; and approximately a dozen siphons of brickwork, under light pressure, were reported for Boston.

Of those inverted siphons which were described as installed on the separate system, three quarters consist of but a single pressure pipe each. All those in Brockton and all in Salem,— five in each city, — have two pipes; and examples are also found in a dozen other towns. In a single case, on the trunk-line siphon in North Easton, there are three pipes.

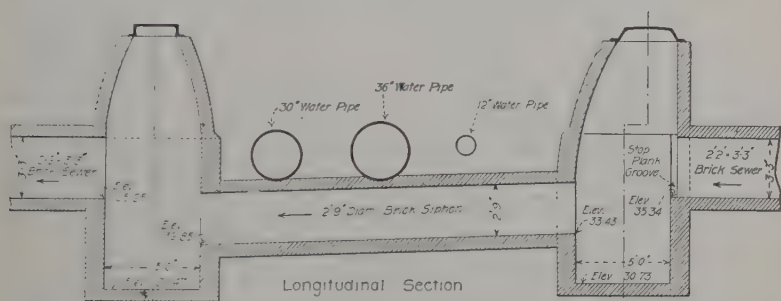


FIG. 5. — BRICK SIPHON IN CALUMET STREET SEWER, BOSTON, MASS.

With inverted siphons on combined sewers the proportions are but little different from the above. Most have but one pipe; five installations with two pipes were reported for Boston, and examples are also found in Cambridge, New Bedford and Somerville. At Belle Isle Inlet, on the North Metropolitan main line, there is a three-pipe siphon, also two on the interceptors at Worcester.

Outside of the Metropolitan main sewers, and the line under Dorchester Bay of the Boston Main Drainage System, the various inverted siphons reported upon, including both separate and combined systems, range in length from 5 ft. to about 5300 ft., and in diameter from 4 in. (one case) to 78 in. (one case). At least a dozen of these, namely, at Andover, Easthampton, Fitchburg, Gardner, Milford, North Attleboro, North

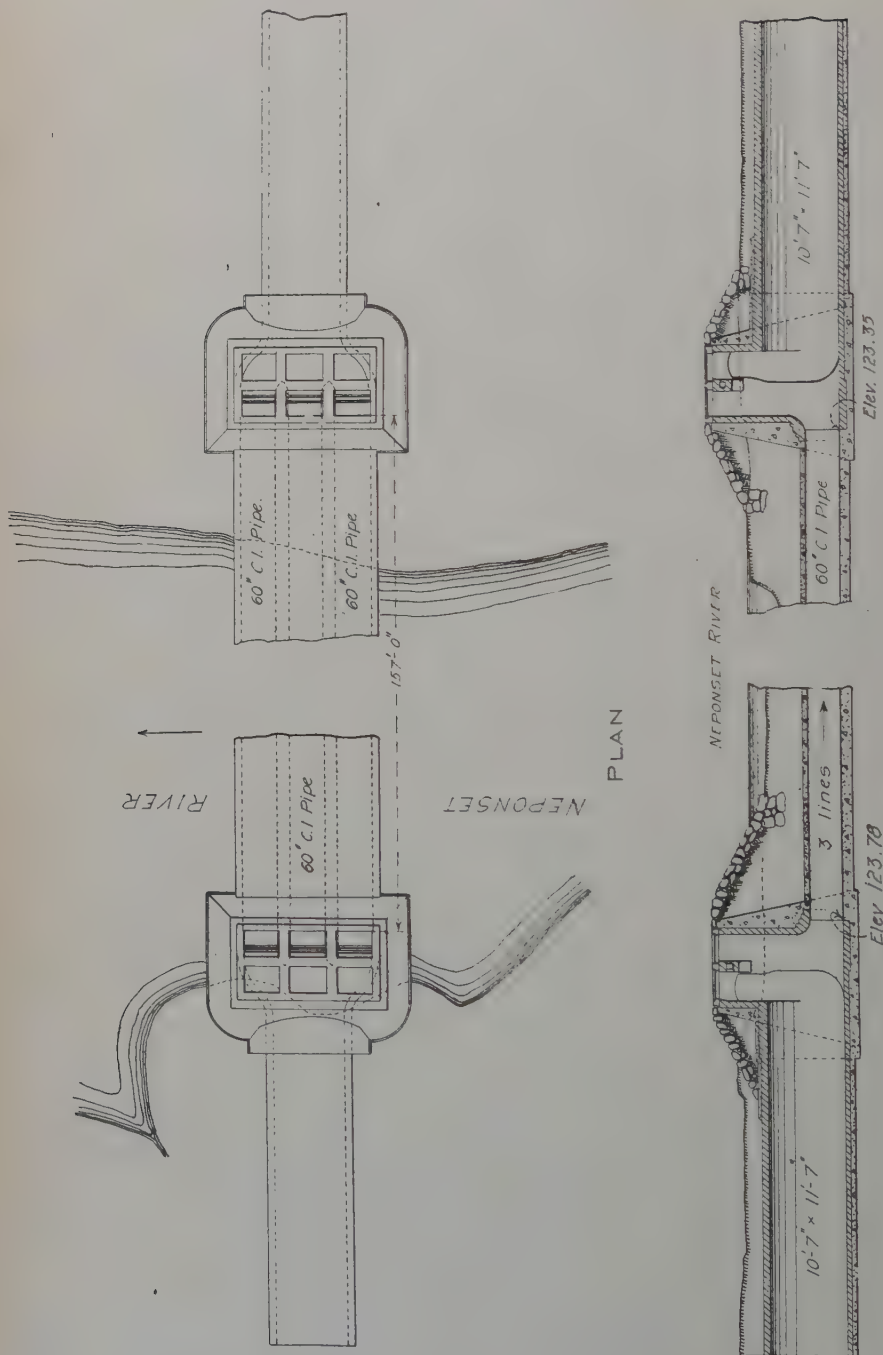


FIG. 6. — NEPONSET RIVER SIPHON IN HIGH LEVEL SEWER, MASS. METROPOLITAN SEWERAGE WORKS.

Brookfield, Norwood and Spencer, ranging from about 500 to about 5 300 ft. in length, were built as a means of reaching certain treatment plants, usually sand filters.

The 4-in. pipe just referred to is used in parallel with a 6-in. in the inverted siphon in West Britannia Street, Taunton. There are nine examples in which single 6-in. pipes are used, in one case up to a length of 1 385 ft., and six others in which they are used in parallel with a 4-, 6-, 8-, or 10-in. For practical reasons the minimum diameter to be considered advisable for inverted siphons is likely to be placed at about the same figure as for sewers in general, say 6 in. or 8 in. on separate systems, and 10 in. or 12 in. on combined. The 4-in. and all but two of the 6-in. siphons above referred to are on separate systems, and all are reported to have been free from serious stoppage, except a pair of 6-in. pipes on Adams Street, Milton, and a 6-in. line at Greenfield. On combined systems the only cases for which a smaller diameter than 12 in. was returned were the old Hampshire Street siphon in Lawrence, built in 1885, 8 ins. in diameter, reported to have been frequently clogged; a combination of 8-in. and 12-in. in parallel, on Berwick Street, Somerville, installed in 1886, and stated to have been free from stoppages, and two 6-in. siphons in Greenfield.

Certain questions on the Committee's blanks were aimed at bringing out the head provided in design for the individual inverted siphons, but were so interpreted in answering as not to prove very helpful. The available head is approximately the difference in levels of the invert of the main sewer on reaching and on leaving the siphon. As thus defined, its value appears in a number of returns to be not more than 0.1 ft., which is barely sufficient to provide velocity head alone for a velocity of 2.5 ft. per second. These cases are of rather short siphons, not over 60 ft. long, and nearly all on separate systems, but it seems probable that the actual head required is produced by a back-water rise of level in the approaching sewer. The head to be provided tends to increase with the length of the siphon, owing to the greater friction loss, and the highest value reported is 17.25 ft., for the 6-in. siphon under Raspberry Brook valley, Longmeadow, 1 385 ft. long.

Overflows are provided on about 30 of the inverted siphons, presumably discharging in most cases into the streams under which the siphons pass. They have the manifest value on a combined system of being able to relieve the siphon of a surplus of storm water; and on any single-pipe siphon, of allowing it to be temporarily cut off for cleaning, without requiring sewage to be stored upstream in the pipe system.

Blow-offs for emptying the inverted siphon during cleaning operations are reported in 18 cases.

Much diversity of practice appears in the matter of providing sumps at inverted siphons. For 16 siphons sumps are reported at the upper end, for 32 at the lower end, for 17 at both ends, and for 58 at neither end.

In the great majority of inverted siphons in this state no special provision for flushing has been installed. In several cases, however, flushing gates have been provided at the head of the siphon, and in five others reliance is placed on the use of stop-planks; at the head of 15 siphons connections of from 2 ins. to 6 ins. diameter have been made to water mains; at Concord and North Brookfield are examples of the use of storage tanks automatically discharged by true siphons, and at the West Bartlett Street inverted siphon in Brockton there is a 12-in. connection for flushing with river water. On three of the New Bedford siphons there is a special clean-out connection for the insertion of rods when needed.

In the matter of maintenance it is to be noticed that flushing is the principal reliance for keeping the inverted siphons clear. On 54 out of 83 siphons in Massachusetts for which we have returns on this point, flushing is used, being supplemented on 32 of them by cleaning with tools, usually at less frequent intervals, while in 11 cases tools are said to be the only method employed. In about one third of those cases in which flushing is resorted to, it is applied once a year, in an equal number of others at intervals of from two to six months, in half as many others at intervals of from one week to four weeks, and in two instances, in Concord, sewage is stored and automatically discharged into inverted siphons at intervals of between two and

three hours. From these figures it is evident that many of the siphons are flushed more frequently than the main sewer systems.

As to the cost of cleaning inverted siphons very little definite information was elicited. In most cases it was stated that data were not available. In ten the cost was said to be nothing, or very slight, but for 15 siphons figures were given. The highest was \$350 for the Huntington Avenue siphon under Muddy River, Boston — Brookline; and the next highest was \$285, for the Gaylen Street siphon under the Charles River in Watertown, a 24-in. pipe, 290 ft. long, flushed once a year and cleaned twice a year by other means. The cost given for the Adams Street siphon, in Milton, was \$160; this has two 6-in. pipes, 52.5 ft. long, and is flushed once a month and cleaned by other means two or three times a year. In the dozen other cases reported the cost ranged from \$1 to \$45.

None of the siphons reported upon in this state has ever had to be dug up on account of stoppage, but fourteen have been seriously clogged, as follows:

1. Mystic Street siphon under Mill brook, Arlington; two 8-in. pipes, 38 ft. long, separate system. Cleaned by diverting sewage through overflow to stream and pumping water from clean-out chambers.

2. Siphon at pumping station, Brockton; two pipes, 10-in. and 12-in., 60 ft. long, separate system. Cleaned with rods.

3. Washington Street siphon at Village brook, Brookline; single 12-in. line, 33 ft. long, combined sewer. Partly stopped, but cleaned by by-passing sewage and scraping out deposit.

4. Walter Ave. siphon at Morse Ave., Brookline; single 12-in. line, 19 ft. long, combined sewer. Partly stopped, but cleaned by by-passing sewage and scraping out deposit.

5. Brookline Street siphon at Douglas Street, Cambridge; single 12-in. line, 90 ft. long, separate system. Stopped once, but cleaned with rods.

6. Huron Avenue siphon, Cambridge; single 10-in. line, 18 ft. long, separate system. Cleaned by scraping.

7. Line under Green river, at Greenfield; single 6-in. pipe, 106 ft. long, combined sewer. Lower manhole filled with deposit and flow stopped.

8. Line under Green river, at Greenfield; single 24-in. pipe, 127 ft. long, combined sewer. Lower manhole filled with deposit and flow stopped.

9. Hampshire Street siphon under Spicket river, Lawrence; single 8-in. pipe, 94 ft. long, combined sewer. Said to be frequently stopped. Cleaned by diverting sewage through overflow to river, scraping out siphon pipe and flushing with hose stream from hydrant.

10. Auburn Street siphon, Medford; single 10-in. line, 157 ft. long, separate system. Cleaned by dragging rope through pipe.

11. Adams Street siphon, Milton; double line of 6-in. pipe, 52 ft. long, separate system. Pumped out, and presumably cleaned with rods.

12. Arlington Street siphon, Watertown; two pipes, 10-in. and 15-in., 38 ft. long, separate system. Stopped once, soon after construction, from mason having left some of his staging in manhole.

13. Gaylen Street siphon under Charles river, Watertown; single 24-in. line, 290 ft. long, separate system. Stopped twice in one year, pumped out, and cleaned by further means which were not stated.

14. Southbridge Street siphon, Worcester; single 24-in. line, 126 ft. long, separate system. Cleaned by scraping.

APPENDIX C.

DETAILED DESCRIPTIONS OF CERTAIN INVERTED SIPHONS
IN MASSACHUSETTS.

Amesbury, Mass. (Boston Soc. C. E., 1916, J. L. Woodfall.) Built under Powow river. Separate system. Siphon built in 1912. Length, 570 ft. Iron. One line. 16-in. Low point, 12.5 ft. below inlet and 11.5 ft. below outlet. Inlet sewer, 15-in., grade, 1/1 000; outlet sewer, 18-in., grade, 1/1 600. Siphon considered good for 2.5 ft. per second velocity and 1 700 gals. per minute discharge. Provided with 6-in. water-pipe connection for flushing.

A second siphon at Amesbury passes under a small brook. Built in 1912. Length, 338 ft. Vitrified pipe. One line. 12-in. Inlet and outlet sewers also 12-in. Low point, 7 ft. below inlet and 4 ft. below outlet. Siphon considered good for 5.5 ft. per second velocity, and about 1 900 gals. per minute discharge. Provided with connection to water main at manhole for flushing.

Andover, Mass. (Boston Soc. C. E., 1904 and 1916, J. L. Woodfall.) Built under a valley to reach filter beds. Separate system. Siphon built in 1898. Length, 4 980 ft. Iron. One line. 12-in. Low point 66 ft. below inlet and 53.5 ft. below outlet, latter at settling tank. Siphon considered good for velocity of about 2.5 ft. per second, and discharge of about 900 gals. per minute. Flushing provided for by connection with 6-in. water main. Blow-off gate at low point, discharging upon small filter bed. In 1904, Mr. Woodfall stated that measurements by the State Board of Health showed an average daily flow of about 125 000 gals. and a velocity in the siphon of 0.25 ft. per second. Up to that time no trouble had been experienced with the siphon; it had been flushed but once from the water main, and the blow-off gate had not been opened at all for flushing.

Easthampton, Mass. (Boston Soc. C. E., 1916, J. L. Woodfall.) Built in highway, in 1904. Separate system.

Length, 736 ft. Iron. One line. 14-in. Inlet sewer, 12-in. on 0.0018 grade; outlet sewer, 15-in. on 0.0015 grade. Hydraulic gradient for siphon 0.003. Siphon considered good for 2 ft. per second velocity, and about 1 050 gals. per minute discharge. Has blow-off gate at low point.

Gardner, Mass. (Boston Soc. C. E., 1904, J. L. Woodfall.) From Conant Street, under valley of Pond brook, to filtration area. Separate system. Siphon built in 1890. Length, 1 050 ft. Iron. One line. 12-in. Lowest point, 25.4 ft. below upstream sewer and 24 ft. below outlet. Slope of hydraulic gradient, 0.00133. Manhole at upper end. No sump. Terminates in settling tank. Crosses Pond brook in covered box supported on short bridge. 8-in. blow-off branch at lowest point, near brook, discharging onto small filter bed. Siphon built with leaded joints, under 4 to 4.5 ft. cover, changes in direction and grade with straight pipe. Put in operation in spring of 1891. Blow-off opened several times in summer of 1891, again in summer of 1896, again about 1901, but not otherwise previous to 1904. Considerable sludge discharged each time blow-off gate was opened. Substantial amount of rags and other solids discharged into settling tank every day. Evidence of intermittent clogging of siphon at times, and self-clearing under resulting increased head. Measurements indicated average velocity in siphon of about 0.4 ft. per second, in 1904. Siphon not flushed from July, 1898, until February, 1899.

	Discharge.	Loss of Head.
Before flushing	398 000 gallons per day	0.886 ft.
Before flushing	422 000 gallons per day	0.940 ft.
After flushing	255 000 gallons per day	0.230 ft.
After flushing	412 000 gallons per day	0.509 ft.
Computed for clean water....	255 000 gallons per day	0.102 ft.
Computed for clean water....	412 000 gallons per day	0.263 ft.

In discussion by Sanitary Section, Boston Soc. Civ. Engrs., April 5, 1916, Mr. Woodfall gave maximum working capacity of siphon under normal conditions at about 700 gals. per minute, and corresponding velocity about 2.5 ft. per second.

Gardner, Mass. (Boston Soc. C. E., 1904 and 1916, J. L. Woodfall.) Inverted siphon under valley of Otter river to fil-

tration area. Separate system. Siphon built in 1900. Length, 2 600 ft. Iron. One line. 16-in. Lowest point, 38.2 ft. below upstream sewer and 32.5 ft. below outlet. Slope of hydraulic gradient, 0.0022. For purpose of storage, last 427 ft. of 12-in. upstream sewer built of 30-in. vitrified pipe. From this pipe the flow may be sent through a dosing chamber containing two 18-in. Miller siphons, to the inverted siphon, or may be by-passed direct if desired. The dosing tank was installed to give intermittent flow to the filter beds, but is not now so used, though available for flushing the inverted siphon. Main reliance for flushing is placed in a connection at the head of the inverted siphon to a 6-in. water main under 350 ft. head. In using this connection a 16-in. gate just upstream on the inverted siphon is first closed. There is no blow-off on the line. The discharge goes to a settling tank and thence to sand filters. In 1904 the average daily flow, as measured by the State Board of Health, was 250 000 gals. Mr. Woodfall considered the siphon good for about 1 900 cu. ft. per minute and a velocity of 3 ft. per second.

Gardner, Mass. (Boston Soc. C. E., 1916, J. L. Woodfall.) On South Gardner outlet, on line with old and new filter beds. Separate system. Siphon built in 1904. Length, 776 ft. Iron. One line. 16-in. Inlet sewer, 15 in.; outlet sewer, 18-in. Lowest point of siphon, 11.2 ft. below inlet, and 8.2 ft. below outlet. No special provision for flushing, but blow-off gate provided at low point. Siphon considered good for a velocity of about 4 ft. per second, and discharge of 2 600 gals. per minute.

Another inverted siphon built on same line in same year. Length, 514 ft. Iron. One line. 16-in. Inlet and outlet sewers, 15-in. Low point of siphon, 6.7 ft. below inlet and 4.3 ft. below outlet. No special provision for flushing, but blow-off gate provided at low point. Siphon considered good for a velocity of about 4.5 ft. per second, and discharge of 2 900 gals. per minute.

Fitchburg, Mass. (Boston Soc. C. E., 1916, and the Semi-Annual Report of Sewage Disposal Commission, Dec. 31, 1912. H. P. Eddy, Cons., Engr., David A. Hartwell, Chief Engineer.) Passes from siphon chamber at lower end of 48-in. intercepting

sewer, down the valley of the Nashua river, across under the river to high land taken for the treatment works. Built in 1912. Combined system. Length of siphon from siphon chamber, about 5 300 ft. Cast iron. One line. 30-in. Hydraulic gradient for siphon, 0.0029. Invert at lowest point, 51.9 ft. below invert of 30-in. pipe at siphon chamber. Discharging capacity placed at 13 250 000 gals. per 24 hours. Grit chamber about 1 400 ft. above siphon chamber. A 36-in. connection provided at siphon chamber for additional siphon pipe to be added in the future when necessary. Overflow at siphon chamber for excess storm water during considerable rains, with 24-in. pipe line to spill it into river. Gate, with 24-in. blow-off pipe to Nashua river, at lowest point of siphon. One year after the siphon was put into service it was opened and examined throughout its length. The only accumulation found was about six cu. yds. of sand at a point where there is a sharp turn in the pipe. The average flow in the intercepting sewer in 1910 was only about 4 000 000 gals. per day, equivalent to a velocity of about 1.25 ft. per second in the siphon, and the minimum was equivalent to less than 1 ft. per second. At the blow-off connection a plank was found wedged.

APPENDIX E.

NOTES RELATING TO CERTAIN INVERTED SIPHONS OUTSIDE OF MASSACHUSETTS.

The data tabulated in Appendix D relate to certain inverted siphons which have been selected as having special interest for one reason or another. Some are large structures in important systems, others are of the multiple conduit type with carefully designed regulating and inspection chambers, and still others were constructed by methods of special interest, particularly by tunneling.

Aberdeen, Scotland. This inverted siphon is of particular interest because of its size, about 6 ft. 6 in. in diameter, divided vertically by a division wall making two conduits each about 6 ft. 6 in. high by 3 ft. 0 in. wide and semi-circular in section. The siphon was constructed under considerable difficulty, using a cast-iron bolted lining which was grouted. A special sump at the lower ends is of interest because of the provision made for draining the siphon by means of a centrifugal pump installed for this purpose.

Paris, France. The two siphons listed are of interest not only because of their size and length, but particularly because of the construction methods adopted to overcome the difficulties encountered. One was constructed of steel pipes and the other was constructed in tunnel, using a cast-iron lining which was later grouted.

Buenos Aires, Argentina. This inverted siphon, which was constructed in 1919 by tunnel methods, involved the use of 557 tons (2 000 lbs.) of cast-iron segments for the lining. These segments were bolted together through flanges on the outside with joints broken longitudinally. A shield was used in the tunnel and compressed air was required to overcome the hydrostatic pressure. Two shafts, 14.75 ft. square, lined with concrete, inside a steel caisson, were sunk one on each side of the river, 443 ft. apart. The invert of the tunnel is about 58 ft. below

low water in the river. For a depth of about 51 ft. below the low-water line, the soil encountered was mud, below this was a bed of stiff clay, approximately 10 ft. thick, overlying beds of water-bearing sand.

Binghamton, New York. This three-pipe inverted siphon has inspection and clean-out chambers at each end on the straight run of the lower part of the siphon, designed so that access can be easily had to any part of the siphon for flushing or for cleaning with rods, as may be necessary. It also has an overflow to the river protected by a backwater gate. There are four such siphons on the intercepting sewer system, all of the same general type, but varying in the sizes of pipe used and in the length of the siphon. The reference given illustrates the siphon in considerable detail.

Carlisle, Pa. This inverted siphon has a 12-in. cast-iron pipe laid above the siphon, connected with the creek so that flushing water may be admitted to the siphon for flushing purposes.

Chicago, Ill. The Lawrence Ave. sewer is 16 ft. in inside diameter, constructed of several rings of brick. The siphon under this sewer is of unusual design, in that it is constructed on an arc having a radius of about 15 ft., rather than with two vertical shafts and a horizontal connection, as is the usual form of siphon. The siphon is illustrated in the reference given.

Hattiesburg, Miss. This 8-in. inverted siphon has a length of 2 860 ft., a maximum depth of 11 ft. below the inlet end, and a difference of 1 ft. in elevation between the invert at the inlet and at the outlet end. It gave no trouble during the first eight months of operation. It is stated that a flow of 40 000 gals. per 24 hrs. from the State Normal School appeared to maintain a self-cleansing velocity in the siphon. This rate in an 8-in. pipe will give a velocity somewhat less than 0.2 ft. per sec.

A tee and a shear valve were placed at the stream crossing to permit emptying the siphon, and for flushing with water from a near-by fire hydrant in case of clogging. About 300 ft. of the siphon beneath the creek bed was laid with cast-iron pipe, the remainder being vitrified clay pipe. The joints in the clay pipe were poured with "Jointite," and in the case of iron pipe with

lead. With no allowance for friction losses, the maximum hydrostatic head on the clay pipe is given as 9.5 ft.

Louisville, Kentucky. In 1907 work was begun on a comprehensive sewerage system for the city under the direction of the Commissioners of Sewerage, J. B. F. Breed, Chief Engineer, Harrison P. Eddy, Consulting Engineer. This work involved the construction of a number of stream crossings, built as inverted siphons. Ten of these are given in the tabulation in Appendix D.

The siphon in Section A of the Middle Fork sewer at the crossing of the South Fork of Beargrass Creek is illustrated in *Am. Sew. Prac.*, Vol. I, page 574, and is more or less typical of the general design adopted. Provision is made for carrying the dry-weather flow of sewage through one or both of the two 12-in. cast-iron pipe lines with an overflow dam permitting storm water to pass over and through the 36-in. cast-iron pipe. Control of these pipe lines is also maintained by means of valves and stop-planks.

The inverted siphon on Section B of the Middle Fork sewer follows the same general principle, but provides for the dry-weather flow in a single 12-in. pipe line, with a 24-in. and a 30-in. pipe line to care for the higher rates of sewage flow. Vitrified pipe encased in concrete was used instead of cast-iron pipe. A chamber with adjustable stop-planks was provided at each end of the siphon, so that dams can be formed at predetermined heights controlling the flow through the several conduits. An emergency overflow to the creek was also provided at the upper end. The maximum depression of the invert of the 30-in. pipe in this siphon was about 3.7 ft. below the invert of the sewer at the upper end, while the maximum depression in the preceding siphon was about 5.9 ft.

The inverted siphon on Section D of the Middle Fork sewer (see Fig. 7) has three conduits, 12-in., 16-in. and 20-in. in diameter respectively, all constructed of cast-iron pipe encased in concrete. Chambers at each end provide for control of the flow through the conduits, and at the inlet end there is an inspection chamber by which access can be had to the horizontal run of the three conduits at their lowest point. There is also an emergency overflow in this chamber. The maximum depression of the invert

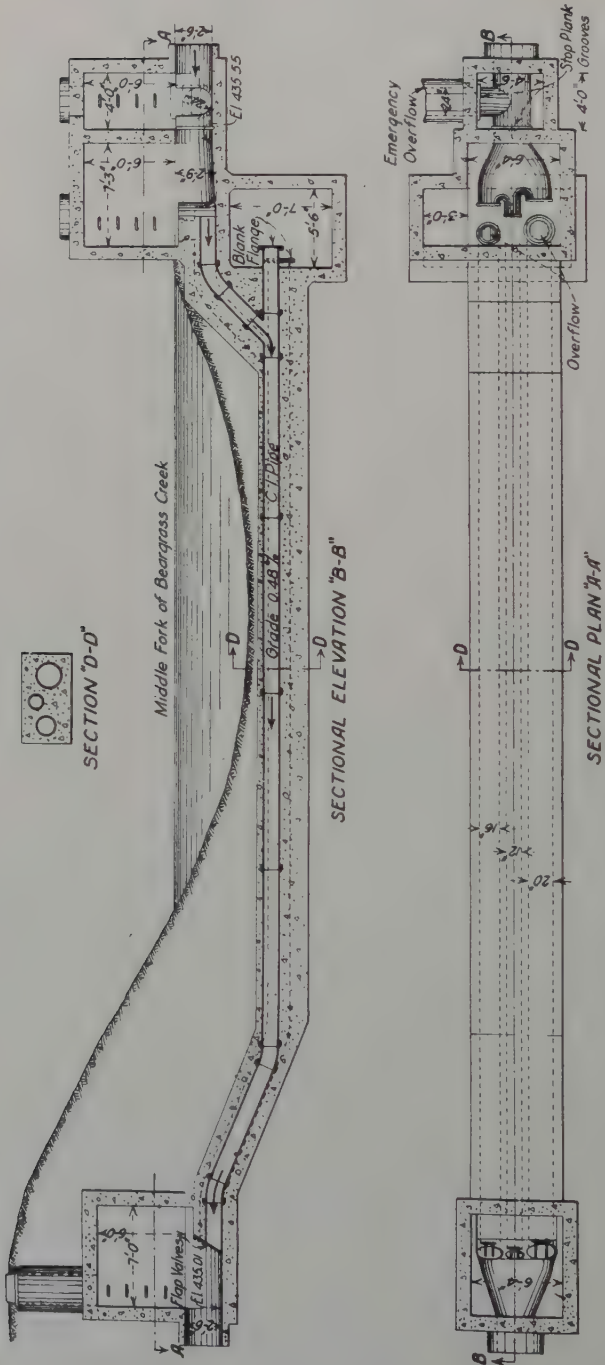


FIG. 7. — SEC. D MIDDLE FORK SEWER SIPHON, LOUISVILLE, KY.

of the 20-in. pipe below the invert of the sewer at the upper end is about 5.5 ft.

In designing all three of these siphons, it was intended that the smallest pipe be used as long as it has sufficient capacity to provide for the quantity of sewage flowing. When this capacity is overtaxed, it is expected that the flow will be transferred to the next larger pipe, which will be continued in use until such time as its capacity is overtaxed, when the largest pipe will be put into service and the other two temporarily thrown out of use. Later on, two or more pipes can be placed in service, so that at all times it should be possible to provide sufficient velocity through the siphon to prevent deposit. Thus far experience has shown that this is the case.

There are three inverted siphons on the Northeastern Sanitary Trunk sewer carrying sewage from a separate system. The inverted siphon on Section A is illustrated in *Am. Sew. Prac.*, Vol. I, Fig. 248, p. 574. Also in the report of the Commissioners of Sewerage, Jan., 1910, pp. 65 and 147. It consists of three lines of vitrified pipe encased in concrete, one 18-in., and two 30-in. These pipes are so graded that when the sewage is shut off they will drain to one low point in the creek bed where a clean-out chamber has been constructed. Control-valves and stop-planks have been provided for the operation of the siphon in the manner previously described. The maximum depression of the invert of the 30-in. pipe is about 15 ft. below the elevation of the invert of the sewer at the inlet end.

The inverted siphon on Section B of the Northeastern Sanitary Trunk sewer has three lines of cast-iron pipe encased in concrete, a 16-in. and two 20-in.

There is no depression in the invert of this siphon, but the crown is depressed to a maximum of 14 ins., because of the change from a 30-in. sewer above and below the siphon to the 16-in. pipe, where the siphon crosses under the bed of Edwards Pond branch. Special chambers have been provided at each end of the pipe lines with stop-planks for controlling the flow, as previously described.

The inverted siphon on Section C of the Northeastern Sanitary Trunk sewer is somewhat similar, but the maximum depres-

sion of the invert is about 16 ins. The sewer above and below the siphon is 24 ins. in diameter and the crossing under the creek is made in two cast-iron pipes, one 16-in. and a 20-in. There is a manhole at each end for inspection and cleaning purposes, but no regulating stop-planks or gates. An overflow to the creek is provided at the upper end.

There is an inverted siphon on the Enterprise sewer connection where it crosses under Beargrass Creek. The dry-weather flow in the 6-ft. diameter brick sewer is diverted by means of a dam, two ft. high, into a regulator chamber controlled by a float-operated regulating valve which discharges into one or both of two vitrified pipe lines encased in concrete. One line is 10 ins. in diameter and the other 12 ins. At the outlet end there is a chamber in which the vitrified pipe can be removed and access gained to the horizontal run of the siphon for cleaning and inspection. The maximum depression of the invert of the 12-in. pipe in this siphon below the invert of the Enterprise sewer is about 7.5 ft. Sliding gates have been provided at the inlet end of each pipe and a flap valve at the outlet end, so that either or both of the pipes may be placed in operation at any time. In addition, a branch pipe leading from each siphon pipe in the regulating chamber and below the sliding gate allows an overflow into the second pipe when only one is in commission.

An inverted siphon was necessary to carry the Cooper St. sewer connection under the improved channel of Beargrass Creek. This siphon consists of one 8-in. vitrified pipe encased in concrete. The maximum depression of the invert is about 6.6 ft. below the invert of the sewer at the upper end. Near the outlet end a clean-out manhole has been built, with a gate valve to shut off the flow when cleaning the siphon. The flow into the siphon connection is controlled by a float-operated regulating valve. A drawing of this inverted siphon is given in the report of the Commissioners of Sewerage, March 1913, p. 92.

An inverted siphon was required to carry the Phoenix Hill sewer connection under Beargrass Creek to the Beargrass interceptor. Sewage from the Phoenix Hill sewer is diverted into a regulator manhole, and the flow controlled by a float-operated regulating valve, discharging into an 8-in. cast-iron pipe encased

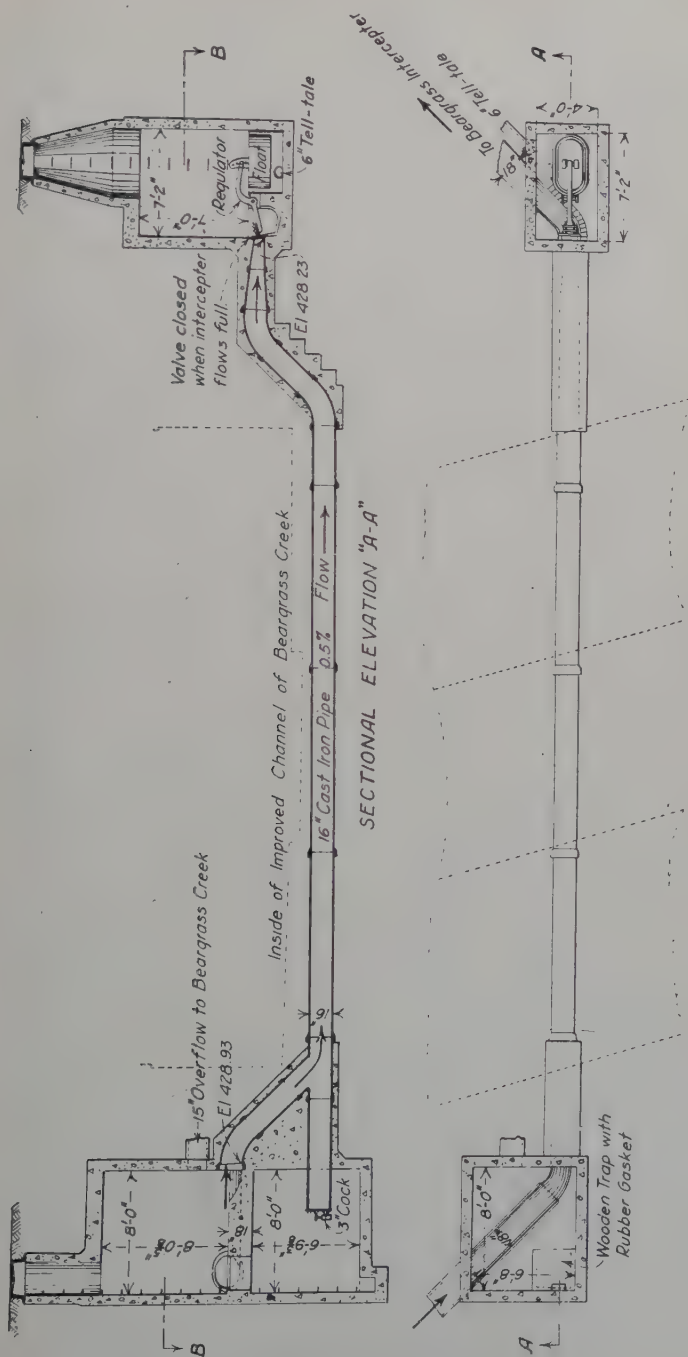


FIG. 8. — BRENT ST. AND BROADWAY SEWER CONNECTION UNDER BEARGRASS CREEK, LOUISVILLE, KY.

in concrete. Near the discharge end is a valve and clean-out manhole in which a section of pipe can be removed in case it is necessary to put rods into the pipe. This design is similar to that of the Cooper St. sewer siphon. The invert of the siphon at the lowest point is depressed about 4 ft. below the invert of the siphon at the inlet end, and about 10 ft. below the invert of the sewer beyond the regulator chamber.

The Brent St. and Broadway sewers are connected to Beargrass Creek through a 16-in. cast-iron pipe inverted siphon (see Fig. 8). The pipe has been depressed a sufficient amount, about 4.8 ft. maximum, to clear the inside of the proposed concrete channel for Beargrass Creek. The discharge into the siphon is controlled by a regulating valve, float operated, set in a regulator chamber similar to the design of the Cooper St. and Phoenix Hill siphons. At the discharge end of the siphon is an inspection chamber with a clean-out leading directly into the horizontal run of the siphon. Access to the inspection chamber is had through a manhole in the discharge chamber of the siphon.

Milwaukee, Wisconsin. There are a number of inverted siphons on the intercepting sewers leading to the Jones Island Sewage treatment plant. The following description includes five, of which three are high-level siphons and two low level. The low-level siphons discharge into the suction wells of the low-lift pumping station, whereas the high-level siphons discharge directly into the sewage treatment plant, with the exception of one, which is under the Milwaukee river and discharges into one of the other siphons leading to the treatment plant site.

The high-level siphon from Second and Scott Sts. to Jones Island begins as a 48-in. cast-iron pipe with invert at the inlet end at approximately El. 14.6 and extends for a length of 5 684 ft. to the foot of Park St., where the invert elevation is approximately minus 10.2. The siphon then drops vertically in a concrete shaft having a wetted area of 12.92 sq. ft. and a wetted perimeter of 13.46 sq. ft. to El. minus 54, then continues in a concrete tunnel having a wetted area of 12.51 sq. ft. and a wetted perimeter of 10.14 ft., a distance of 798 ft. to Jones Island, where the invert elevation is approximately minus 55. The siphon then rises in a shaft 48 in. in diameter, constructed of concrete,

to an open channel 4 ft. wide by 5 ft. 6 in. deep to an invert elevation of approximately plus 4.5. The two 60-in. diameter conduits at the inlet end of the siphon have an invert elevation of approximately 15.5, and there is provision for a future connection 54 in. in diameter at approximately El. 14.6.

The high-level inverted siphon from Mason and Broadway to Jones Island begins as a shaft in the 72-in. diameter sewer, invert elevation approximately 19.4. The shaft has a wetted area of 24.5 sq. ft. and a wetted perimeter of 18.83 sq. ft. The elevation of the invert at the bottom of the shaft is approximately minus 7.6, from which point the siphon continues as a tunnel 51 in. in diameter, constructed of concrete, a distance of 1 822 ft. to Detroit St. and Broadway, where the inverted siphon from Eighth and Sycamore Sts. enters as above referred to. The elevation at this point is approximately minus 8.2, and the size of the tunnel is increased to 60 in. in diameter, constructed of cast iron. This section of the inverted siphon extends for a length of 3 679 ft. to the foot of Erie St., invert elevation approximately minus 9.8, at the head of a shaft constructed of concrete having a wetted area of 28.13 sq. ft. and a wetted perimeter of 19.54 ft. The shaft drops to elevation approximately minus 55.8 and then extends a distance of 938 ft. under the harbor in a concrete tunnel of special section having a wetted area of 28.39 sq. ft. and a wetted perimeter of 19.81 ft., to invert elevation approximately minus 56.9. The inverted siphon then rises in a 72-in. diameter concrete shaft to an open channel 10 ft. wide by 7 ft. 6 in. high, with an invert elevation of plus 2.50. The connection for a future 60-in. cast-iron pipe has been provided at the foot of Erie St.

The high-level inverted siphon from Eighth and Sycamore Sts. to the siphon at Broadway and Detroit St., above described, begins at Eighth St. in the 72-in. diameter sewer, invert elevation approximately 18.9, and extends a distance of 1 443 ft. to Sixth and Claybourne Sts., invert elevation approximately 11.7, to a concrete shaft having a wetted area of 40.0 sq. ft. and a wetted perimeter of 26.0 ft. The shaft drops to elevation plus 1.0, and then the inverted siphon continues as a 72-in. diameter concrete structure, a distance of 2 407 ft., to the concrete shaft at West

Water and Tyler Sts., invert elevation approximately minus 10.8. The shaft has a wetted area of 36.0 sq. ft. and a wetted perimeter of 24.0 ft. The shaft drops to elevation approximately minus 45.2, from which point the inverted siphon continues in a special section having a wetted area of 28.4 sq. ft. and a wetted perimeter of 20.51 ft., a distance of 1 024 ft., to Broadway and Detroit St. Here there are two vertical shafts, 60 in. in diameter each, constructed of concrete, rising from elevation approximately minus 21.2 to elevation approximately minus 8.2 to the connection with the siphon previously described.

The two low-level inverted siphons are of a different type, consisting, in each case, of two vertical shafts connected at the bottom by a tunnel built on a flat grade.

In the case of the siphon at the foot of Park St. the shafts are constructed of concrete 54 ins. in diameter and the connecting tunnel is of concrete of a circular section having a wetted area of 16.2 sq. ft. and a wetted perimeter of 15.0 ft. The invert elevation at the bottom of each shaft is approximately minus 59 and minus 60 respectively.

The low-level inverted siphon at the foot of Erie St. has shafts 42 ins. in diameter of concrete and a connecting tunnel of concrete having a wetted area of 9.6 sq. ft. and a wetted perimeter of 11.83 ft. The invert elevations of the tunnel are approximately minus 60.8 and minus 61.8 respectively. Both of these low-level siphons connect at Jones Island into a common channel 5 ft. wide by 10 ft. deep leading to the low-level pumping station. The invert elevation of this channel is approximately minus 22.0 and the flow line may be estimated as El. minus 18.0. The elevation of the invert of the 72 in. by 48 in. sewer at the foot of Park St. is approximately El. minus 17, and the elevation of the invert of the 68-in. by 49-in. sewer at the foot of Erie St. is approximately El. minus 15.8.

A number of inverted siphons are illustrated and described briefly in the fourth annual report of the Milwaukee Sewerage Commission, January, 1918.

New Jersey Joint Outlet. This siphon under the Elizabeth river, constructed with two 10-in. cast-iron pipes, has special chambers at each end providing for inspection and cleaning of the

pipes. The horizontal run of the siphon pipes has been extended in each direction to enter these inspection chambers. The siphon is well illustrated in the reference given.

New Orleans, La. There are a number of inverted siphons in the New Orleans sewerage system, due to the necessity of frequent crossings of the drainage canals.

One of these siphons is of a different type than the others, and is therefore of particular interest. This one occurs on the main sewer at the crossing of the Third St. canal. In this case the invert of the sewer is about 21 ins. below the bottom of the drainage canal. Two 18-in. cast-iron pipes are laid on a straight line under the drainage canal, and these are of sufficient capacity to carry the minimum flow of the sewer. When the amount of sewage increases to overcharge these two pipes, the sewage will overflow into two 21-in. vitrified pipes laid in concrete as a siphon immediately under the 18-in. pipes. Provision has been made for flushing the 21-in. pipes, and there is an overflow into the drainage canal for use in case of stoppage in the pipes or sewer.

The other siphons are of the more usual type constructed of vitrified pipe encased in concrete and have automatic flush tanks which thoroughly flush out the pipes each day. Details of these siphons are given in the reference.

The large inverted siphon under the Industrial canal, carrying the Florida Ave. drainage canal, has already been referred to in the text of the report.

Philadelphia, Pa. The inverted siphon under Wissahickon Creek is of interest because of the regulating valves used, and the special provision for flushing and inspection of the horizontal run of the pipes. The siphon was constructed with four lines of cast-iron pipe, a 12-in., two 16-in., and a 20-in. The inlet end are provided with gates so that only those pipes will be in service which are required to carry the flow at a suitable velocity. The outlet end of each pipe is provided with a flap valve of special design, and the inspection opening to each pipe has a flap valve of similar type with a hose connection. This siphon is well illustrated in the reference.

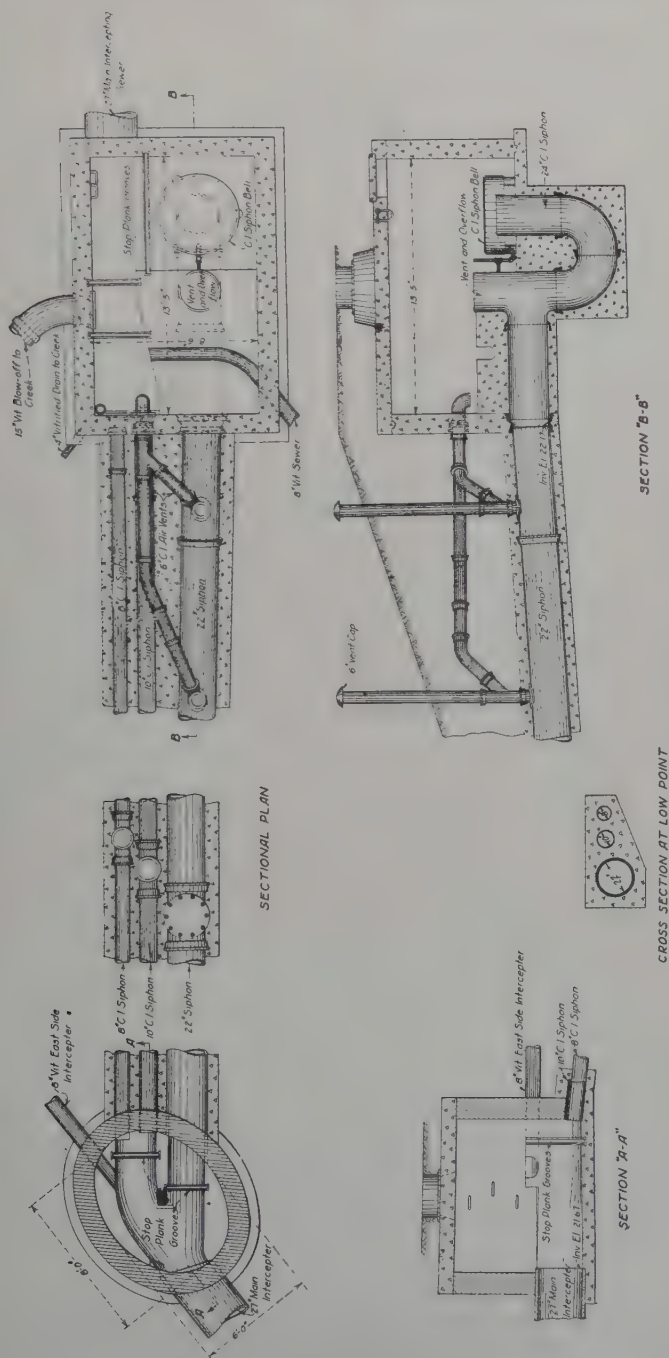
It will be noted that with this form of inverted siphon there is no provision for the automatic regulation of the flow into one

or more pipes. It is intended that the flow shall be controlled by opening or closing valves from time to time, as the quantity of sewage increases, so that desirable velocities will be maintained at all times in the siphon.

St. Louis, Mo. A reinforced concrete inverted siphon of unusual type, designed to carry 2 090 cu. ft. per sec., was constructed at St. Louis at a point where the hydraulic gradient lies above the street level for several hundred feet, the maximum height being about 4 ft. The sewer, 14-ft. in diameter, is increased to a 14-ft. square section in a length of 16 ft., then comes 25-ft. of reinforced concrete section changing from the 14-ft. square section to a section 8 ft. by 27 ft., with a center wall 12 in. wide, forming a double box flume 550 ft. long, having two conduits, each 8 ft. high by 13 ft. wide. Beyond this is a 25-ft. section changing back to the 14-ft. square, and then a 16-ft. reduction section to the old 14-ft. diameter sewer. This siphon is illustrated in the reference given.

Syracuse, New York. An interesting inverted siphon has been constructed where the main intercepting sewer crosses under the improved channel of Onondaga Creek (see Fig. 9). The siphon consists of three pipes laid in concrete, 8-in. 10-in. and 22-in. in diameter respectively. The main sewer is 27 ins. in diameter above and below the crossing. The inlet ends of the 8-in. and 10-in. pipes are provided with blank flanges, so that either one or both of the pipes may be put into use as desired. The flow into the 22-in. pipe is controlled by a flushing siphon, 24-in. size, similar to that used in dosing intermittent sand filters or trickling filters in sewage treatment plants. The flushing siphon has a drawing depth of about 13 ins. The vent of the flushing siphon extends for only a short distance above the maximum flow line, and serves as an overflow in case of failure of the flushing siphon to operate, or in case either of the other two pipe lines become clogged.

For the first few years of operation, the capacity of the 8-in. pipe was expected to be sufficient to carry the flow, and the 10-in. was stopped at each end. During times of storm, when the flow was too large for the 8-in. pipe, the sewage backed up in the main sewer until the siphon on the 22-in. pipe came into action, causing



the surplus flow to be discharged through the 22-in. pipe in doses at a sufficiently high velocity to keep the pipe clean.

When the quantity of sewage exceeds the capacity of the 8-in. pipe, the 10-in. can be put into service instead of the 8-in., and at some future time, when needed, both pipes can be kept in service.

This structure was constructed under the supervision of the Syracuse Intercepting Sewer Board, Glenn D. Holmes, Chief Engineer.

Waterbury, Conn. The Eagle St. siphon was designed to carry the sewage from the 24-in. main sewer under the Naugatuck river. The siphon is constructed of three 10-in. vitrified pipes encased in concrete. The maximum depression of the pipes line under the river is about 8.7 ft. below the invert of the trunk sewer at the entrance. The entrance to each of the three pipe lines is controlled by stop-planks and a flap valve, so that one, two or three of the pipe lines may be brought into service as required by the flow of sewage. Each of the lines may be flushed out by closing the flap valves, filling the manhole with water from a pressure water connection, opening one of the flap valves, and causing the pipe line controlled by that valve to be flushed out at a velocity sufficient to clean out any ordinary deposit in the pipe line.

The details of this siphon are illustrated in the reference given.

APPENDIX F.

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MEMOIR OF DECEASED MEMBER.

EDMUND MORTIMER BLAKE.*

EDMUND MORTIMER BLAKE died at his home in Oakland, California, January 12, 1921. The prominent part taken by Mr. Blake in the Boston Society of Civil Engineers, of which he became a member April 20, 1904, the splendid work accomplished by him in this Society, and, still more, the strong and sincere personal friendship with all the members with whom he came in contact, will make the events of his life of unusual interest.

"Ned" Blake was born in Taunton, Massachusetts, August 13th, 1874, the son of Percy M., a past member of this Society, and Phoebe Sheffield Blake, and was educated in the public schools of Hyde Park, *Amherst College*, class of 1897, Degree Bachelor of Science, Magna Cum Laude, *Harvard University*, Lawrence Scientific School, class of 1899, B. S. in Civil Engineering, Magna Cum Laude.

His early work as a Civil Engineer was as associate with his father, during which time he took charge of the construction of the Sebago Basin for the Portland, Maine, Water Company, this work having been pronounced by competent judges the finest work of its kind ever constructed in Maine.

He was Assistant Engineer, New York Rapid Transit Commission, Eastern Bridge and Structural Company, Worcester, and Brown Hoisting Machinery Company, Cleveland, Ohio.

From 1906 to 1908 Mr. Blake carried on a private practice in sanitary and water-works engineering, designing and installing systems at Wareham, Wrentham, Westford, Hampton Beach, New Hampshire, and the new plant at Provincetown. He organized and was the first President of the Westford, Mass., Water Company.

* Memoir prepared by Henry A. Symonds and N. L. Hammond.

In 1908, Mr. Blake was called to become Manager of the Idaho Irrigation Company, which constructed and developed large irrigation projects, in the Snake River territory, to reclaim the vast tracts of the Idaho desert lands. He also carried on a private practice and installed several town water, irrigation and sewerage works in Idaho, Washington and Oregon.

In 1911, he was called back to Massachusetts, by the State Department of Health, to become engineer in charge of the twelve miles of improvement on the Neponset River.

This work was followed by an engagement on the South Boston Dry Dock, with the Holbrook, Cabot and Rollins Corporation.

When construction of the United States Naval Destroyer Plant at Squantum was begun in 1918, by the Aberthaw Construction Company, Mr. Blake was appointed supervisor of sub-contracts, having charge of work totaling approximately three million dollars.

This work was followed by that of Manager of Sub-contracts in the addition to the plant of the Bethlehem Shipbuilding Corporation at Sparrows Point, Maryland, whence he was transferred in the same year to the Liberty Shipyard of the Emergency Fleet Corporation, at Alameda, California, where he was advanced to Assistant Manager.

While acting in this capacity he placed a contract for forty-eight thousand green piles, the largest single order ever given. During this engagement he handled successfully many difficult problems, requiring great executive ability, and completed his work there, after the abandonment of the yard project by the Government, on the signing of the armistice, by the satisfactory adjustment of twenty-nine claims outstanding.

In December, 1918, Mr. Blake became associated as Production Engineer with Charles R. McCormack and Company, of San Francisco, one of the largest operators in the Douglas Fir Timber industry. His work with this Company had developed to great magnitude and importance.

Putting into this work the intense enthusiasm and energy he had displayed in all his efforts, the opportunity appeared to

have arrived for the realization of his purpose for great accomplishment.

He was instrumental in organizing the National Association of Tie Producers, in 1919, and was elected President for 1921.

Was member of committee to consult with the officials of the Railroad Administration at Washington on matter of fixing prices and territorial restrictions of markets.

Mr. Blake delivered papers upon various phases of the production and preservation of timber, before the National Association of Tie Producers, Boston Society of Civil Engineers, American Wood Preservers Association, the San Francisco Association of Members of the American Society of Civil Engineers, and others. Membership in Societies included Alpha Delta Phi and Phi Beta Kappa Chapters of Amherst College. He married, in 1903, Clara Allen Drake, of Cleveland, who died in 1907.

While in Idaho, he married Miss Grace Twigg, and has one son, Robert Sheffield Blake, eight years old.

He also leaves his father, Percy M. Blake, of Newtonville, a brother, Philip W. Blake, Secretary of the Chamber of Commerce, Cumberland, Maryland, and two sisters, Mrs. Andrew A. Highlands, of Brookline and Mrs. Frederic A. Tennant of Newtonville.

Many papers have been read and published by Mr. Blake in the various engineering periodicals.

He published successfully a novel, "In The Blake Forest," in 1896. His great versatility is made evident by remarkable success in music, being an accomplished musician and composer. In the latter field he composed many of the most popular pieces of the Amherst College music.

In personal appreciation we wish to quote Mr. E. E. Pershall, of the National Association of Tie Producers, at the Chicago Convention in 1920:

"I do want to say this, Blake has certainly stood out as one of the biggest personalities that this Tie Association has brought together. We didn't know Blake before we had the Tie Association. If I didn't get another thing out of this Association but just meeting E. M. Blake, I would feel that all the work

in getting this Association together and everything that we have striven for, and all our efforts in trying to reconcile all the petty things that have come up, was more than justified and that I was well repaid.

He came out of the West. We know the company by reputation only, we never had any competition with them, and Blake has been the outstanding discovery of this Association."

Former Attorney-General Ralph A. Stewart says, "I desire to express to the Boston Society of Civil Engineers a word of appreciation. I knew Mr. Blake for many years, and, during the time he practiced his profession in Massachusetts, intimately. He was a man of splendid ability, fine professional attainments and unbounded enthusiasm. He worked with me in several professional matters, and I learned to know that I could place great reliance upon his judgment, and furthermore his work was thorough and reliable. He was a most engaging man to work with, for he injected into any professional employment enthusiasm and optimism. We became warm friends, and the news of his death came to me as a real sorrow."

In 1916, "Ned" Blake presented a very strong paper "Service for the Society," in which his own enthusiasm and loyalty to the Society and to the profession is evident in every line. It is a fine, clear statement, which should be carefully read and re-read by our members.

There is little to be added, as deeds speak for themselves.

His "Service for the Society," to his friends and to his country have left a lasting influence for the best.

To a legion of friends, the memory of his laughing eyes, his quick sympathy, his generous helpfulness, will remain a rich legacy from that prince of good fellows, Ned Blake.

BOSTON SOCIETY OF CIVIL ENGINEERS
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INDEX TO ADVERTISERS.

	PAGE
A. B. SEE ELECTRIC ELEVATORS, 111 Devonshire St., Boston.....	VI
ABERTHAW CONSTRUCTION CO., 27 School St., Boston.....	XIV
ADAMS, H. S., 108 Ames Building, Boston, Mass.....	V
ASPINWALL & LINCOLN, 3 Hamilton Pl., Boston.....	V
ASSOCIATED ARCHITECTS PRINTING & SUPPLY CO., 21-27 Pearl St., Boston.....	XIV
BAY STATE DREDGING AND CONTRACTING CO., 62 Condor St., East Boston.....	XVI
BEATTIE, ROY H., 10 Purchase St., Fall River.....	XIII
BISHOP, J. W., & Co., 683 Atlantic Ave., Boston.....	VI
BLAIR, ISAAC, & Co., INC., 433 Harrison Ave., Boston.....	IV
COLEMAN BROS., 1 Marginal St., Chelsea.....	XIII
CONVERSE, H. P., & Co., 161 Devonshire St., Boston.....	II
DONOGHUE, P. W., 170 Purchase St., Boston.....	XV
EARNSHAW, H. P. J.....	XIII
EASTERN BRIDGE AND STRUCTURAL CO., Worcester.....	XI
FAY, SPOFFORD & THORNDIKE, 15 Beacon St., Boston.....	V
FORT HILL PRESS, 176 High St., Boston.....	XIV
FULLER, GEORGE W., 170 Broadway, New York.....	V
GOW, CHARLES R. Co., THE, 166 Devonshire St., Boston.....	XII
HALL, JOHN G., & Co., 114 State St., Boston..	XIII
HOLBROOK, CABOT & ROLLINS CORPN., 6 Beacon St., Boston.....	VIII
HOLZER, U., 25 Bromfield St., Boston.....	IX
HUGHES, EDWARD F., 8 Oliver St., Boston.....	XIII
LEDDER & PROBST, 21 Pearl St., Boston.....	XIII
LEY & Co., INC., FRED T., Springfield, Mass.....	III
MAIN, CHARLES T., 201 Devonshire St., Boston.....	IV
METCALF & EDDY, 14 Beacon St., Boston.....	V
NEW ENGLAND FOUNDATION CO., INC., 70 Kilby St., Boston.....	XIII
NEW ENGLAND SAND & GRAVEL CO., 161 Devonshire St., Boston..	IX
OLD CORNER BOOK STORE, 27 Bromfield St., Boston.....	XIII
PALMER, JOHN E., 1012 Old South Bldg., Boston.....	XIII
PENN METAL CO., 65 Franklin St., Boston.....	VI
PENNSYLVANIA CEMENT CO., 161 Devonshire St., Boston.....	XII
PERRIN, SEAMANS & Co., 57 Oliver St., Boston.....	IX

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	PAGE
RAYMOND CONCRETE PILE Co., 80 Boylston St., Boston.....	X
RIDEOUT, CHANDLER & JOYCE, 178 High St., Boston.....	XIII
ROCKPORT GRANITE Co., Rockport, Mass.....	VII
SIMPSON BROS. CORPN., 77 Summer St., Boston.....	VII
SMITH, B. F., & Co., Merchants Bank Building, 79 Milk St., Boston	XIII
STUART, T., & SON Co., Newton, Mass.....	XVI
THE THOMPSON & LICHTNER Co., 136 Federal St., Boston	V
THORPE, LEWIS D., 201 Devonshire St., Boston.....	V
TUCKER, EDWARD A., Co., 101 Milk St., Boston.....	VII
TURNER CONSTRUCTION COMPANY, 178 Tremont St., Boston.....	XV
WALDO BROTHERS AND BOND Co., 181 Congress St., Boston.....	XI
WARREN FOUNDRY AND MACHINE Co., 11 Broadway, New York....	IX
WESTON & SAMPSON, 14 Beacon St., Boston.....	V
WHITMAN & HOWARD, 220 Devonshire St., Boston.....	V
WORCESTER, J. R., & Co., 79 Milk St., Boston.....	V

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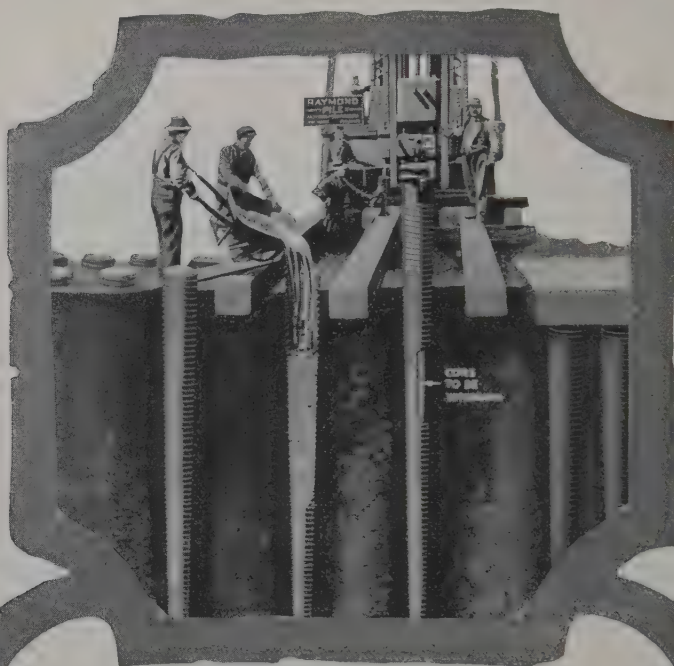
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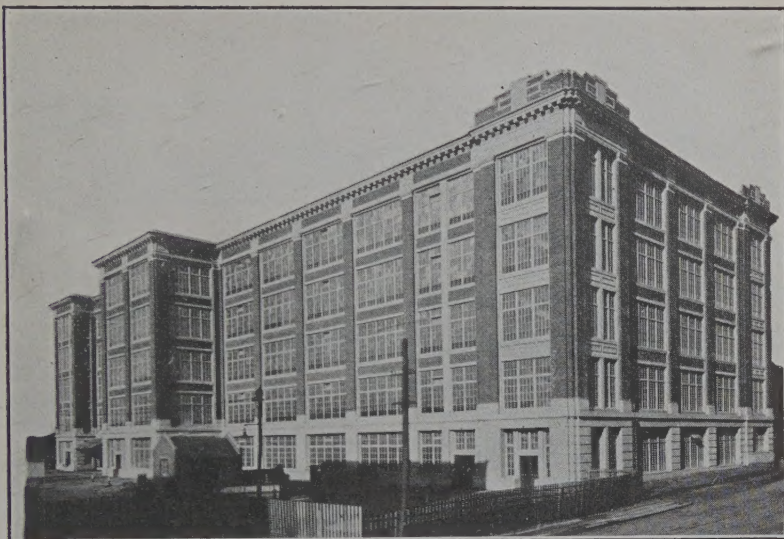
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